Use of CAMS aerosols in HARMONIE-AROME

Daniel Martin-Perez, AEMET

Special thanks to Karl-Ivar Ivarsson, Laura Rontu, Emily Gleeson and Kristian Pagh Nielsen and my colleagues at AEMET.

Joint 29th ALADIN Workshop and HIRLAM All Staff Meeting

1-5 April 2019, Madrid (Spain)

Outline

Use of CAMS aerosols:

- I. Microphysics
  - Introduction
  - Verification results
  - Advances
  - Parametrization of the wet deposition
  - Effects on precipitation
  - Effects on clouds
- II. Radiation
  - Introduction
  - Use of CAMS aerosols
  - Test case
- Other Issues
- Conclusions

I.1. *Microphysics*. Introduction

Aerosol from CAMS are used to obtain the Cloud condensation nuclei (CCN)

"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."

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

Number of levels in the vertical: 60

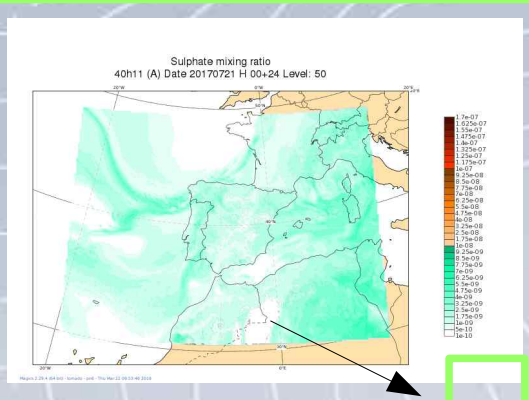
The number of cloud condensation nuclei is used in some microphysical parameterizations (LOCND2 active):

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

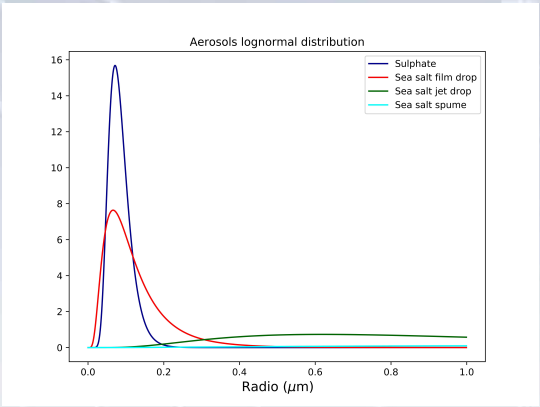
Name	Short Name	Parameter ID
Sea Salt Aerosol (0.03 - 0.5 um) Mixing Ratio	**aermr01**	210001
Sea Salt Aerosol (0.5 - 5 um) Mixing Ratio	**aermr02**	210002
Sea Salt Aerosol (5 - 20 um) Mixing Ratio	**aermr03**	210003
Dust Aerosol (0.03 - 0.55 um) Mixing Ratio	aermr04	210004
Dust Aerosol (0.55 - 0.9 um) Mixing Ratio	aermr05	210005
Dust Aerosol (0.9 - 20 um) Mixing Ratio	aermr06	210006
Hydrophobic Organic Matter Aerosol Mixing Ratio	aermr07	210007
Hydrophilic Organic Matter Aerosol Mixing Ratio	aermr08	210008
Hydrophobic Black Carbon Aerosol Mixing Ratio	aermr09	210009
Hydrophilic Black Carbon Aerosol Mixing Ratio	aermr10	210010
Sulphate Aerosol Mixing Ratio	**aermr11**	210011

I.1. *Microphysics*. Introduction

Mixing ratio of aerosol type



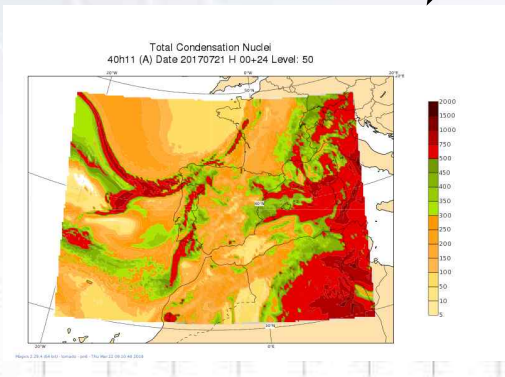
* Mass density of the aerosol particle
* Mean cubic radius of aerosol paricle.
Log-normal size distribution.



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 particles 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

I.1. *Microphysics*. Introduction

Standard configuration:

Three constants for concentration number over sea, land and urban locations:

XCONC_SEA=100/cm3; XCONC_LAND=300/cm3; XCONC_URBAN=500/cm3

CTRL: CONTROL Experiment

Use of CAMS aerosols (Initial configuration):

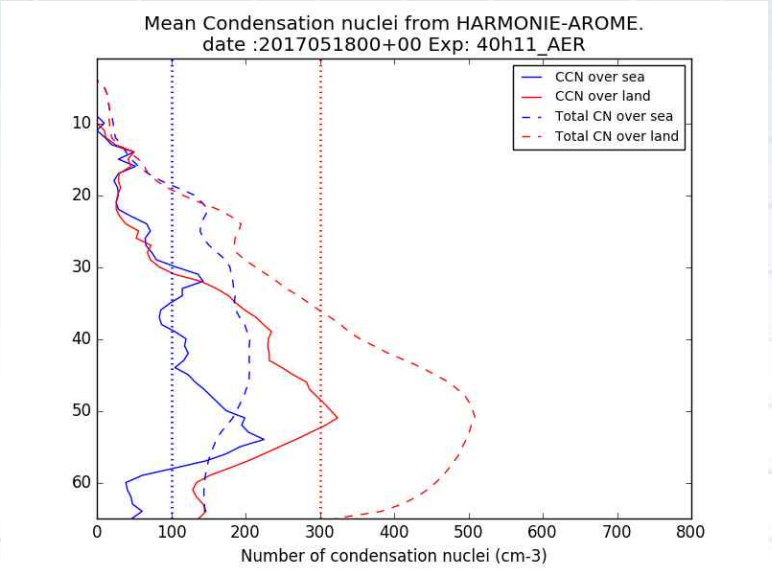
CAMS_0: Initial configuration with CAMS aerosols

*4 3D fields of mixing ratio of aerosols: *3 sea salt types and sulfate*.

* Log normal size distributions are considered for every aerosol field in order to get the number concentration: Two constants for each field (number mode radius and geometric standard deviation) plus the mass density.

*Activated aerosols are calculated using Kohler theory and it depends on the "maximum supersaturation" considered.

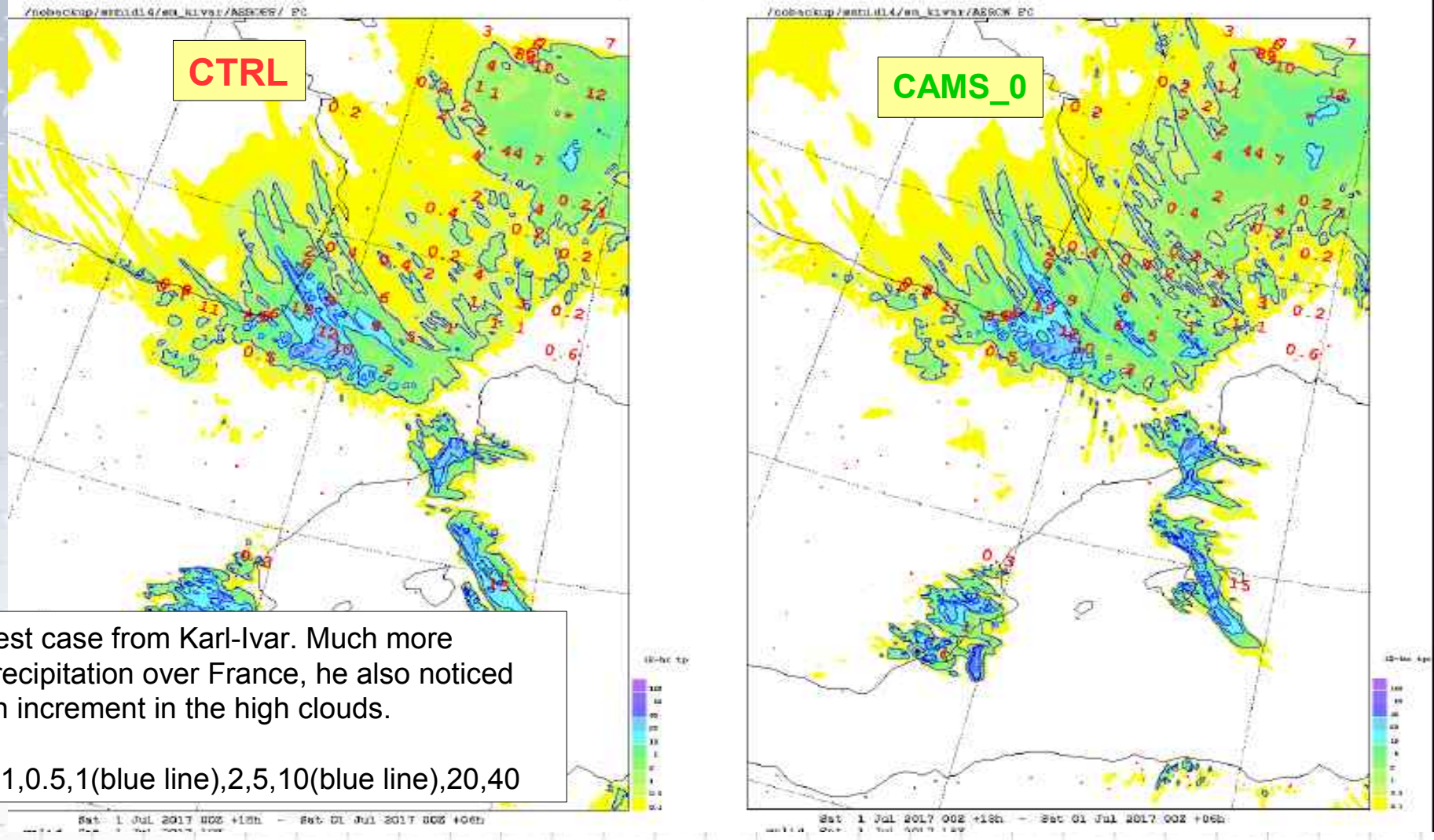
	Number mode radius	Geometric standard dev.	Mass density
Sea salt 1	0.1	1.9	1182
Sea salt 2	1.0	2.0	1182
Sea salt 3	6.0	3.0	1182
Sulfate	0.08	1.4	1600



This changes only affect to ONE VARIABLE in the microphysic.
No other modification has been done in the parametrization.
Some changes need to be done in the parametrization to include the different characteristics of the aerosols.

I.1. *Microphysics*. Introduction

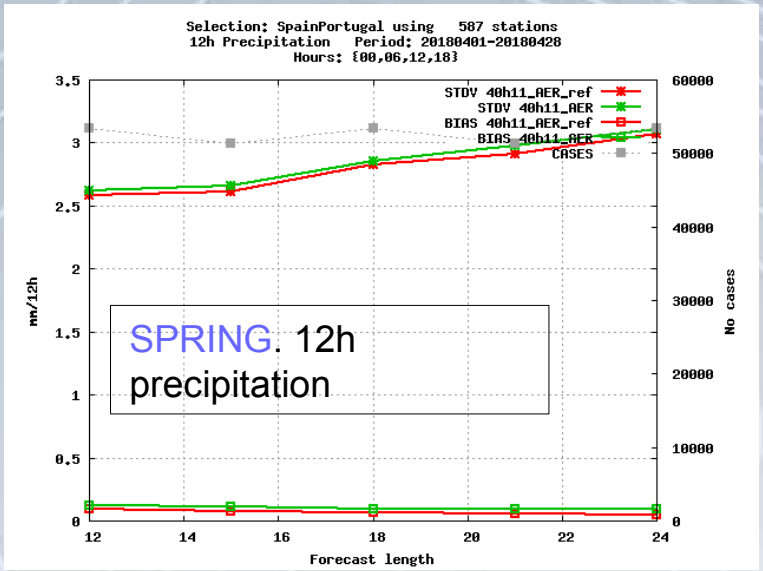
Cold start at 2007-01-01 00 UTC. Precipitation 18-06 UTC. To the left : With no prognostic CCN . To the right it is on. (and much more precipitation over over France) Observation as red numbers, dots means no precipitation.

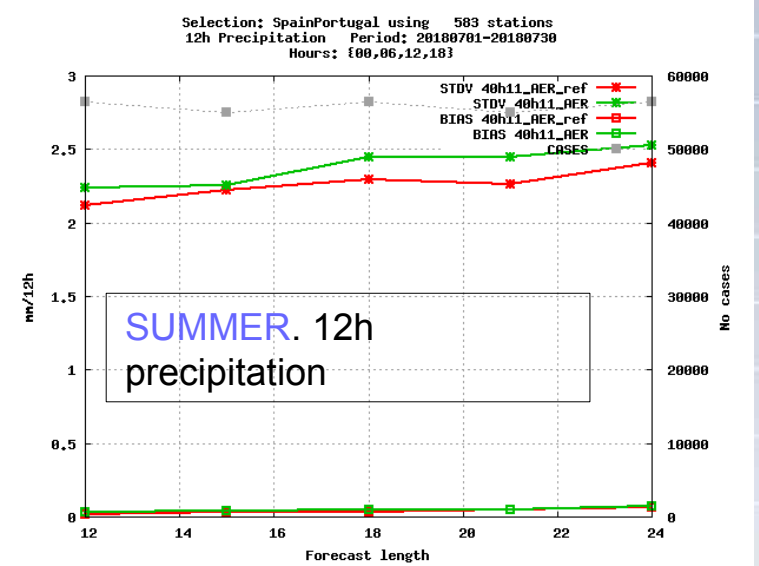


Test case from Karl-Ivar. Much more precipitation over France, he also noticed an increment in the high clouds.

0.1,0.5,1(blue line),2,5,10(blue line),20,40

I.2. *Microphysics*. Verification results





In red the ***reference or control*** *experir*

CTRL: CONTROL Experiment

In green the ***Near real time (n.r.t.)*** *CAMS aerosols experiment (Initial configuration)*

CAMS_0: Initial configuration with CAMS aerosols

Verification for two periods:

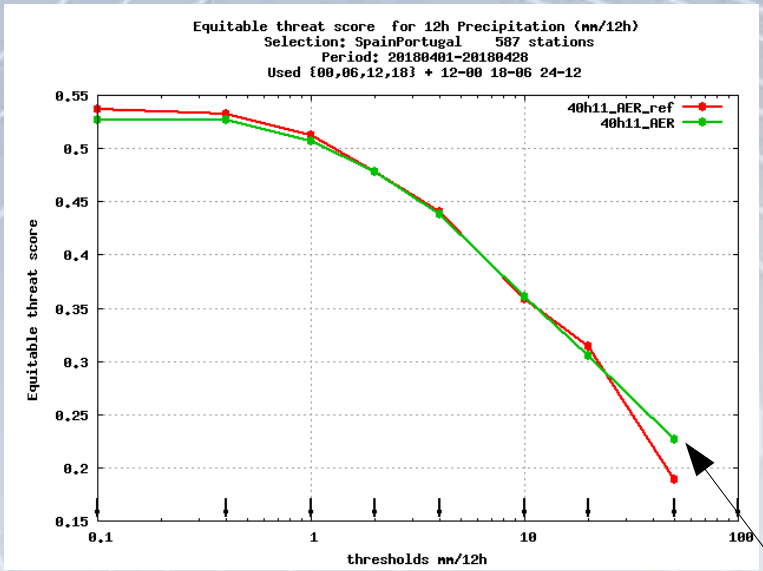
April 2018, very humid

July 2018, dry

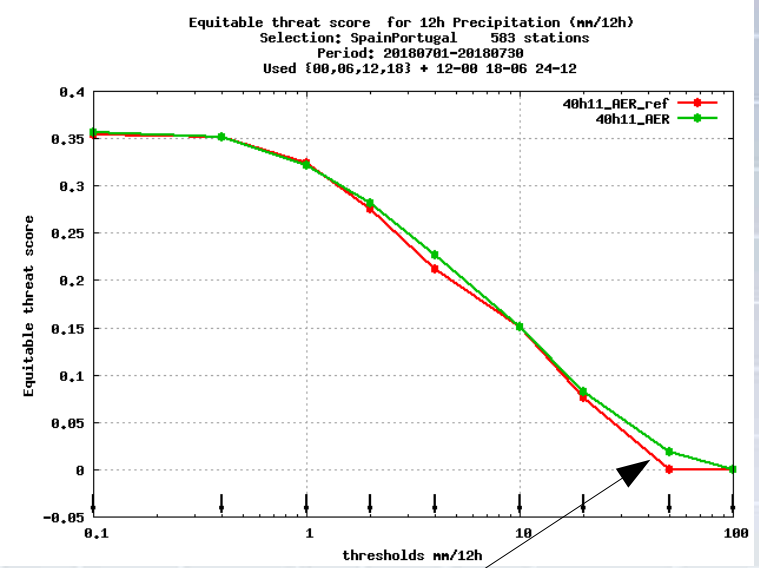
Classical scores doesn't give better results

Similar bias, slightly higher with CAMS aerosols (more precipitation), and higher stdv

I.2. *Microphysics*. Verification results



SPRING. ETS for 12h precipitation

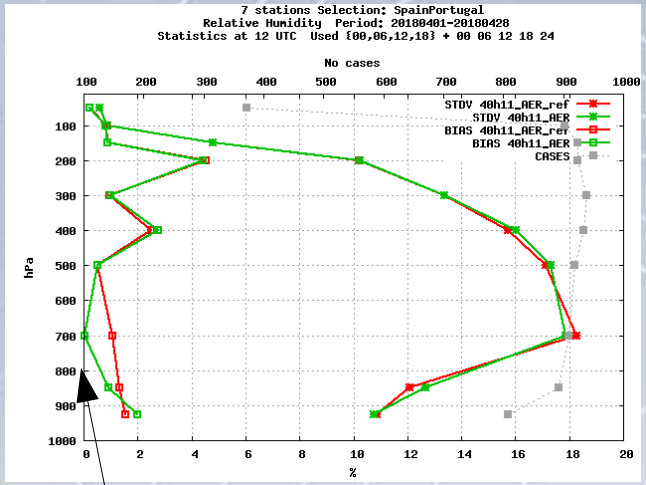


SUMMER. ETS for 12h precipitation

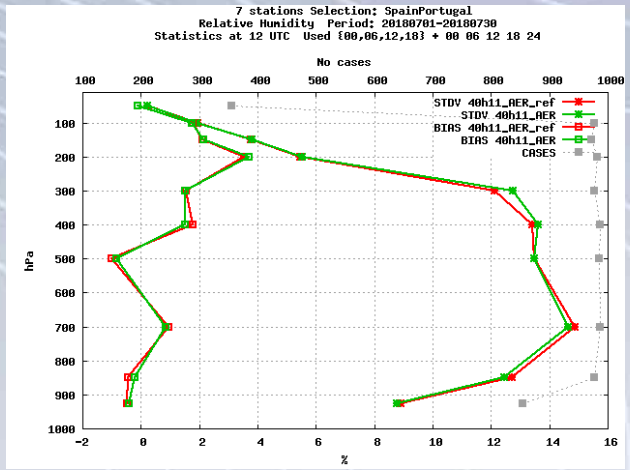
Equitable thread score against thresholds.

For extreme precipitation cases, slightly better results with CAMS aerosols

I.2. *Microphysics*. Verification results



SPRING. Relative humidity profile

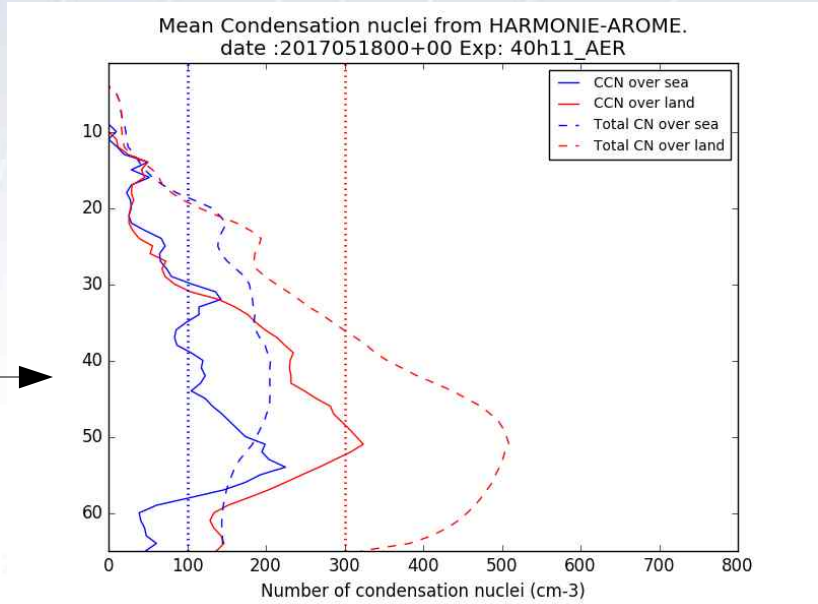


SUMMER. Relative humidity profile

The vertical profile of the RH shows that there is a removal of water vapour in medium levels

Higher values of precipitation might be due to CCN number concentration lower than reference values.

Figure on the right. Vertical structure of the Mean nuclei concentration for n.r.t. aerosol experiment



I.3. *Microphysics*. Advances with aerosols

CTRL: CONTROL Experiment

Standard configuration:

Three constants for concentration number over sea, land and urban locations:

XCONC_SEA=100/cm3; XCONC_LAND=300/cm3; XCONC_URBAN=500/cm3

CAMS_1: New configuration with CAMS aerosols

Use of CAMS aerosols: (Second configuration)

*6 3D fields of mixing ratio of aerosols: *3 sea salt types, Hydrophilic Organic matter, Hydropylic Black Carbon and sulfate*.

* The fields are introduce in the first guess and BC and are advected by the dynamic of the model.

* Log normal distribution are considered for every aerosol field in order to get the number concentration: Two constants for each field (number mode radius and geometric standard deviation) plus the mass density.

*Activated aerosols are calculated using Kohler theory (for organic matter and black carbon the solute effect is not considered). A different approach has been considered.

*Aerosol wet deposition (Mocrette et al., 2009). In-cloud and below cloud scavenging. The fraction of aerosols included in droplets is set to 0.7

	Number mode radius	Geometric standard dev.	Mass density
Sea salt 1	0.1	1.9	1182
Sea salt 2	1.0	2.0	1182
Sea salt 3	6.0	3.0	1182
Hydrophilic organic matter	**0.05**	**2.0**	**1760**
Hydrophilic black carbon	**0.053**	**1.9**	**1800**
Sulfate	0.05 / 0.08	1.8 / 1.4	1600

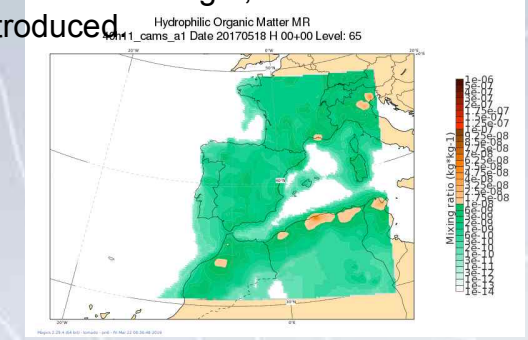
Different values of number mode radius and geometric standard deviation are used in the bibliography. The number concentration is very sensitive to these values!!!

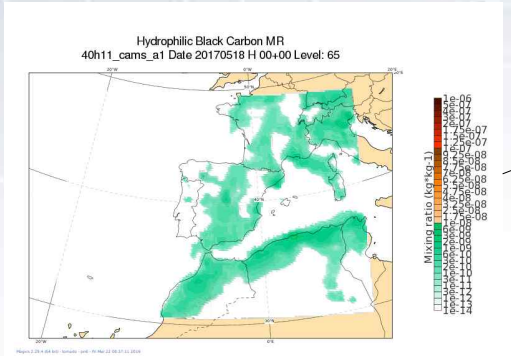
I.3. *Microphysics*. Inclusion of BC and OM

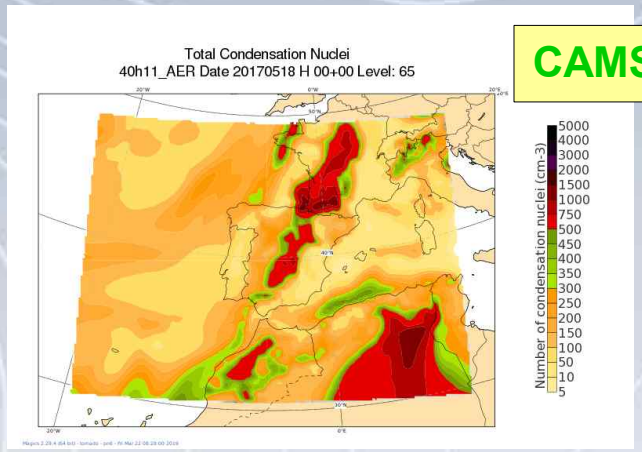
Hydrophilic Black Carbon and Organic matter have been introduced as CN. As a consecuence the total number of CN is increased specially in lower levels.

On the top right, the total number of CN due to sulfate and sea salt for the lower level of the model on 18/05/2018 for time step 0.

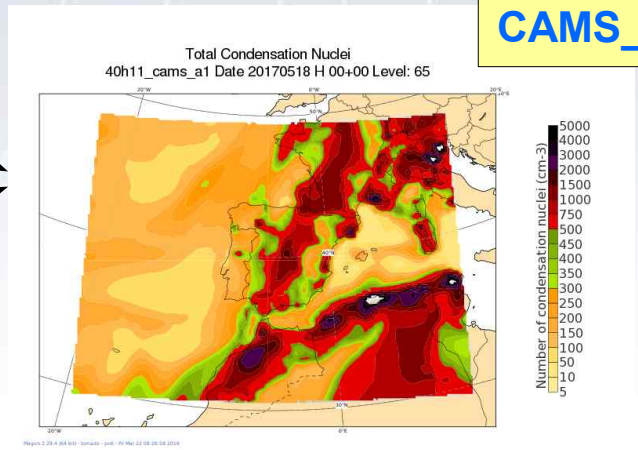
On the bottom right, the same when OM and BC are introduced.







CAMS_0

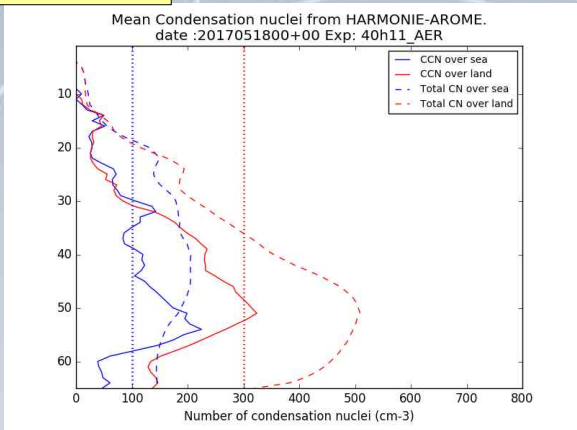


CAMS_1

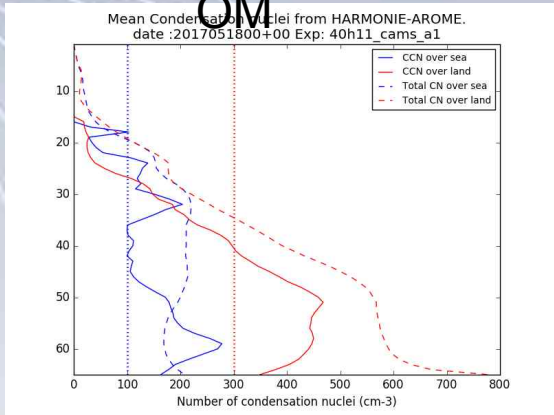
Mixing ratios of OM (top) and BC (bottom)

I.3. *Microphysics*. Inclusion of BC and OM

CAMS_0 Sea salt + Sulfate



CAMS_1 Sea salt + Sulfate + BC + OM

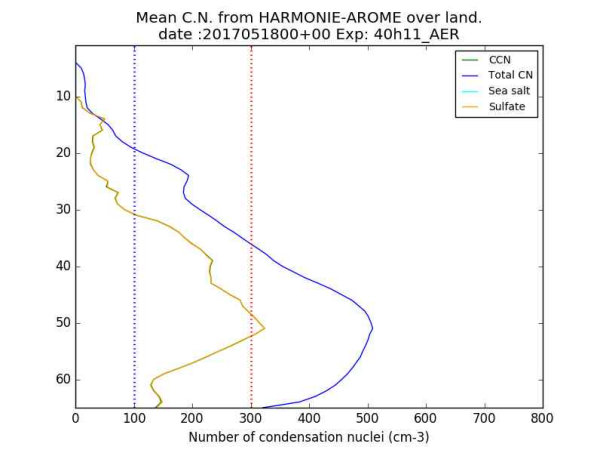


Vertical structure of the Mean Condensation nuclei number and the activated cloud condensation nuclei number obtain for the whole domain.

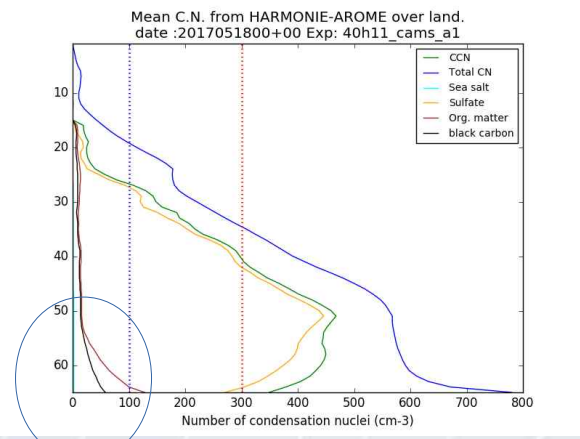
Blue color: over sea; Red color: over land
Continuous line: CCN; Dashed line: Aerosol number concentration.

There is an incremente in CCN between $CAMS_1$ and $CAMS_0$ specially over land.

CAMS_0 Sea salt + Sulfate



CAMS_1 Sea salt + Sulfate + BC +

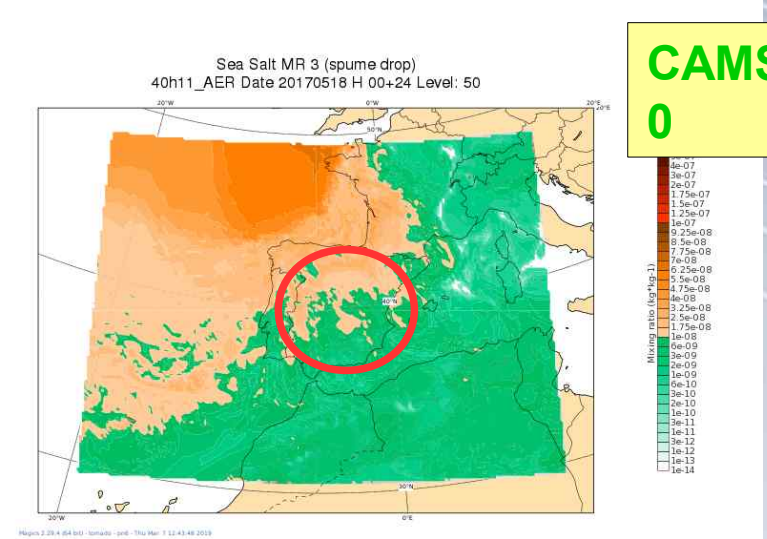


Vertical structure of the Mean Condensation nuclei number and the activated cloud condensation nuclei number obtain for the whole domain.

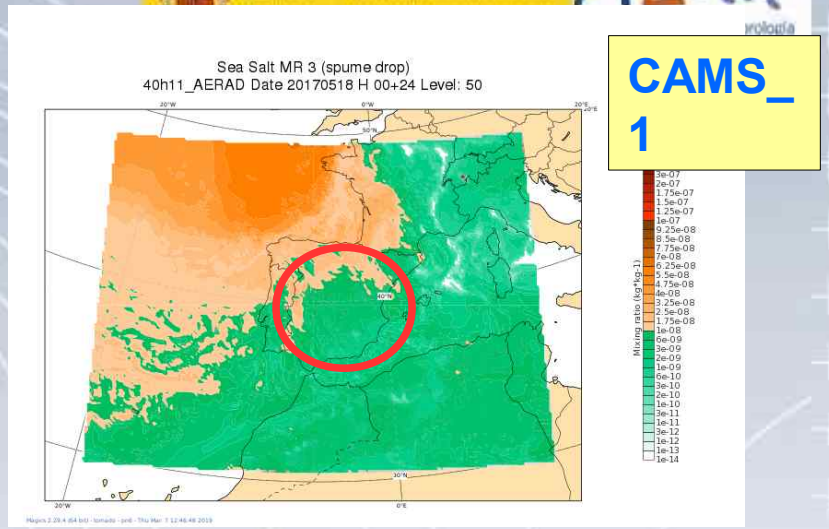
The most important aerosol is the sulfate

Black Carbon and Organic Matter increase the CCN mainly in lower levels → **How relevant are they in fog cases?**

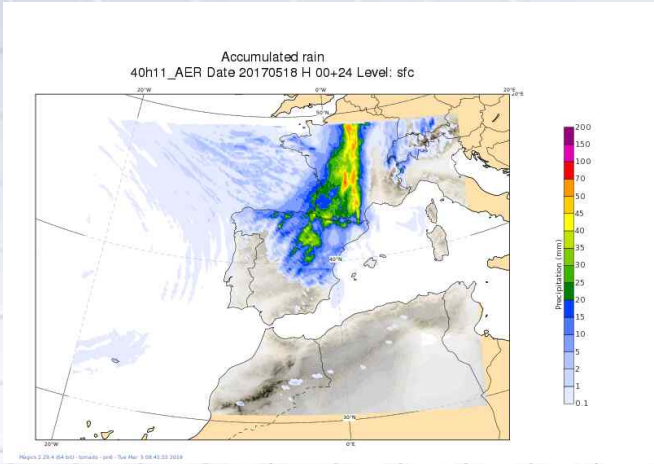
I.3. *Microphysics*. Parametrization of the wet deposition.



Sea salt mixing ratio (spume drop) level 50
Without wet deposition parametrization
Date: 2017051800 Tstep:24



Sea salt mixing ratio (spume drop) level 50
With wet deposition parametrization
Date: 2017051800 Tstep:24

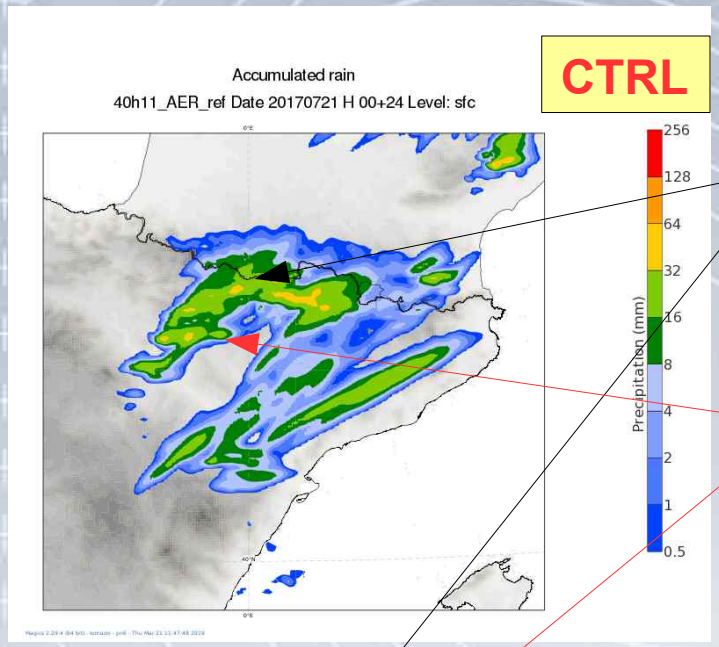


24h rain precipitation. 2017051800

Wet deposition has been parametrized following Mocrette et al., 2009.

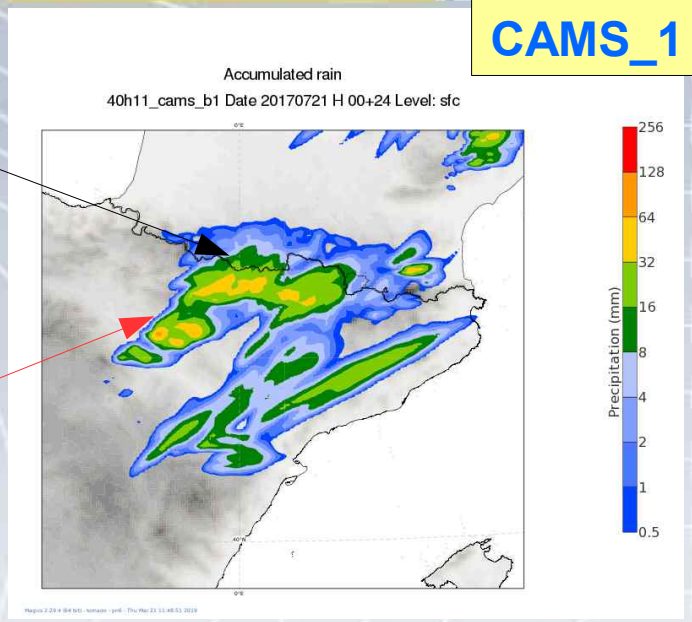
This case shows the removal of sea salt in level 50.

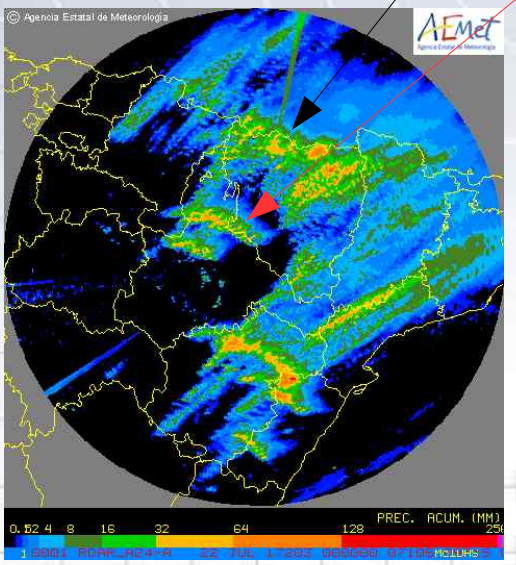
I.5. *Microphysics*. Effect on the Precipitation.



South of Pyrenees

S of Pre-pyrenees.





Test case: 21/07/2017. Precipitation on the NE of the Iberian Peninsula.

In this case it is shown how the introduction of aerosols can modify the intensity of the precipitation.

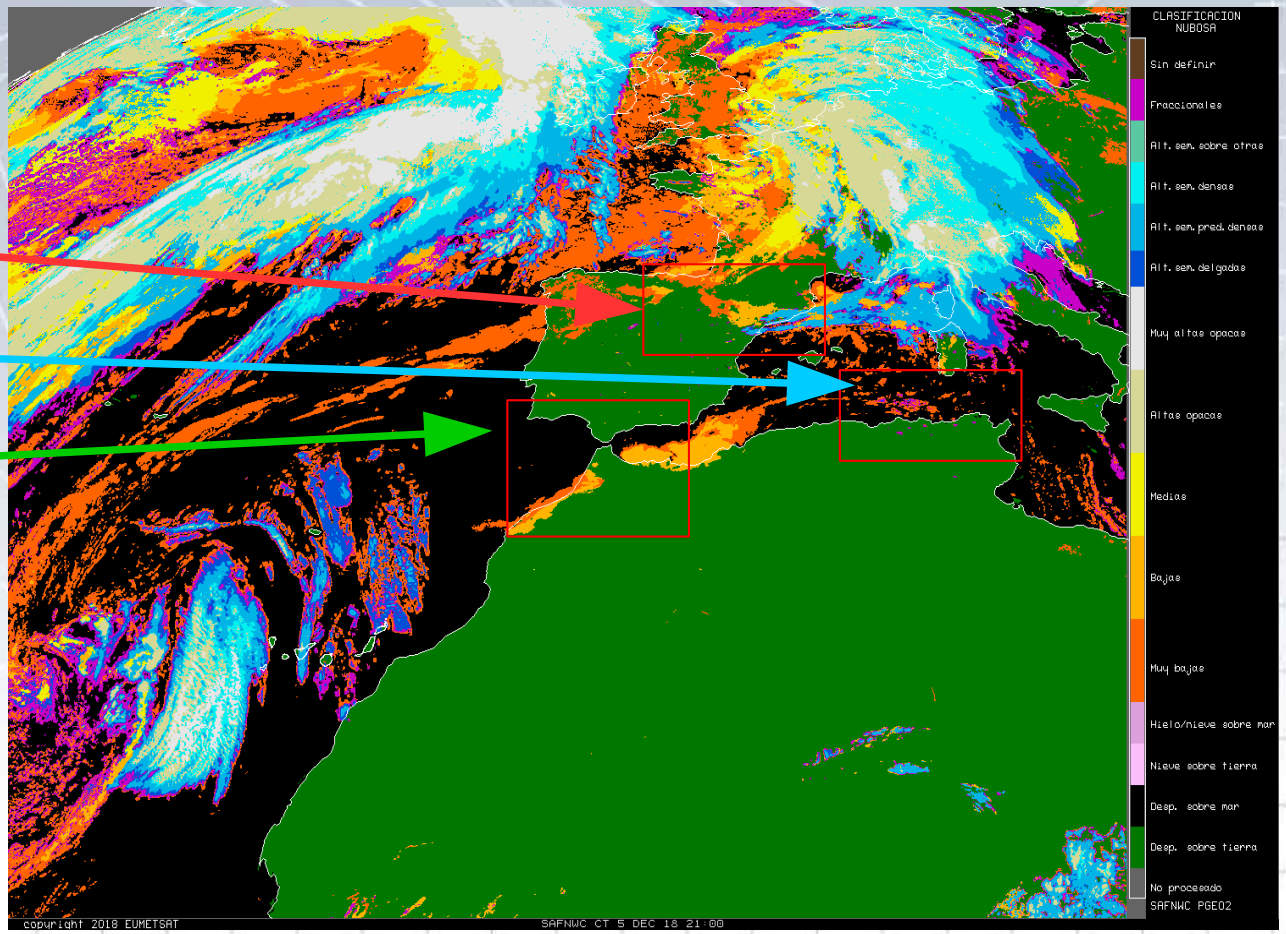
Increment in the precipitation, better agreement with the radar accumulation retrieval.

I.4. *Microphysics*. Effect on the clouds.

Effect of aerosol on fogs. Date **5th of December 2018.**
Image from the NWC SAF. (Orange: very low clouds, light orange: low clouds)

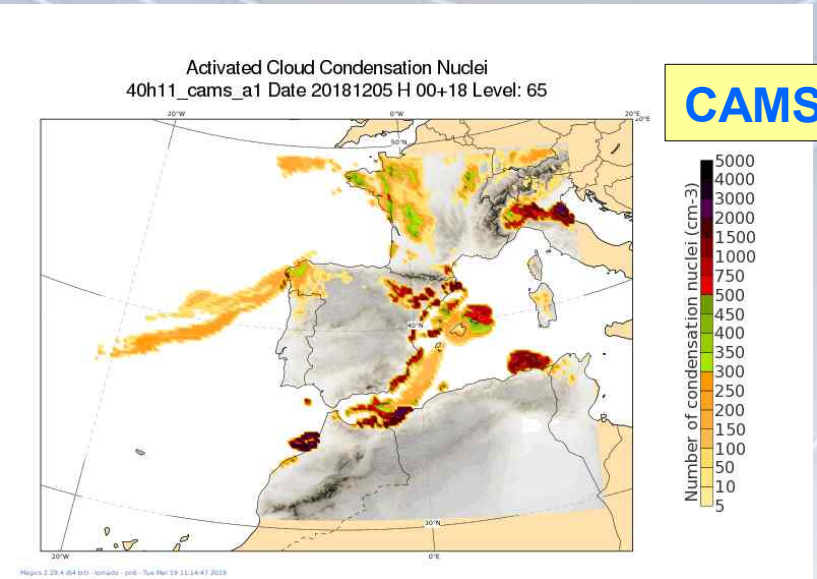
We focus in three areas:

- The Valley of the river Ebro
- The north coast of Algeria and Tunez
- The Morocco coast

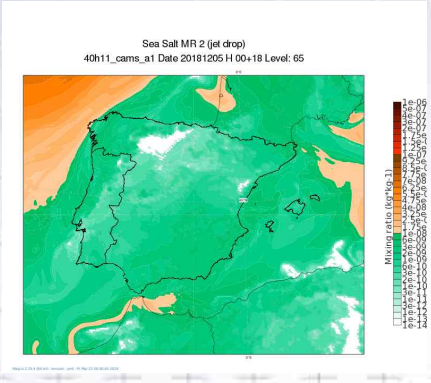


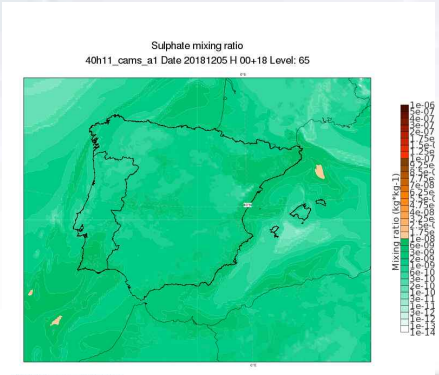
I.4. *Microphysics*. Effect on the clouds.

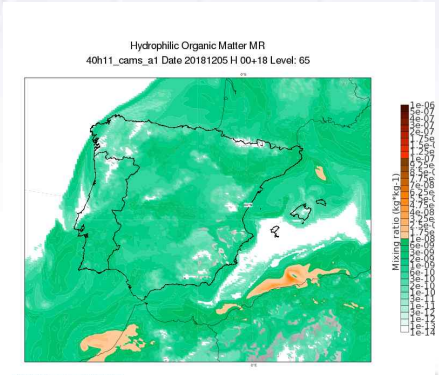
Activated CCN in the lower level of the model.

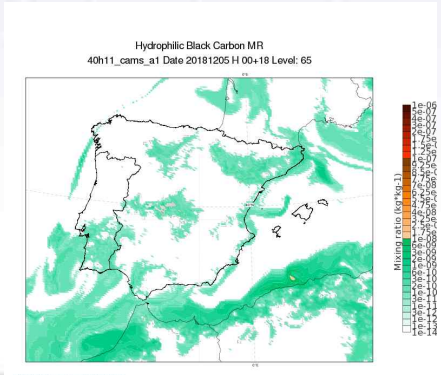


CAMS_1

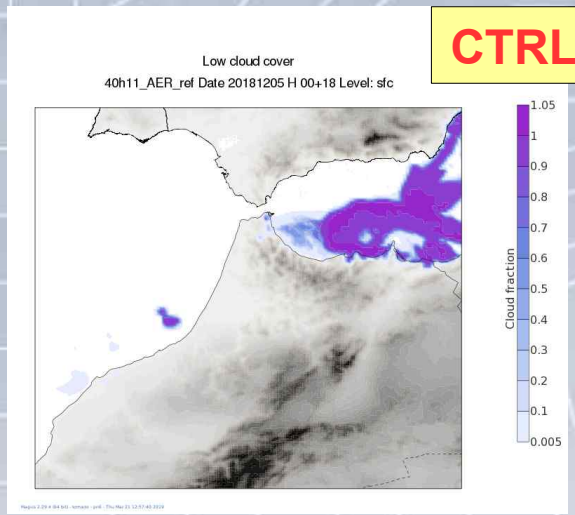






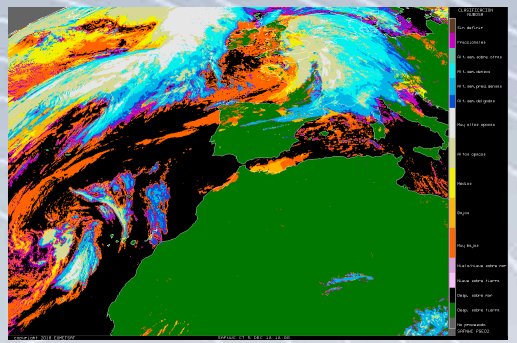


I.4. *Microphysics*. Effect on the clouds.

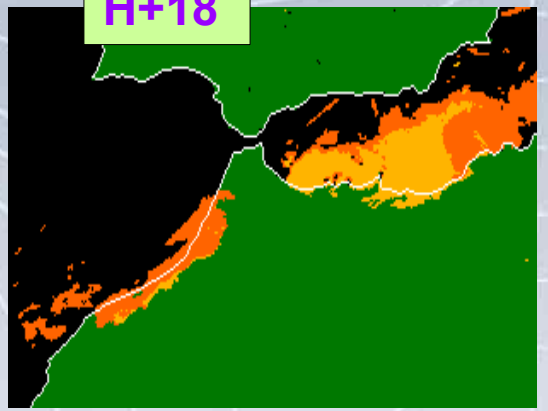


CTRL

NW coast of Morocco.

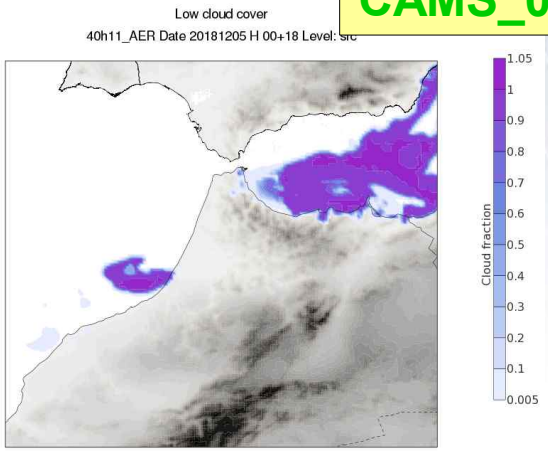


H+18

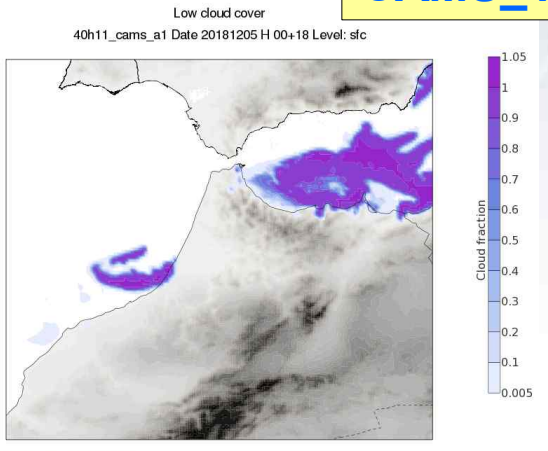


Low cloud cover 05/12/2018 H+18

CAMS_0



CAMS_1

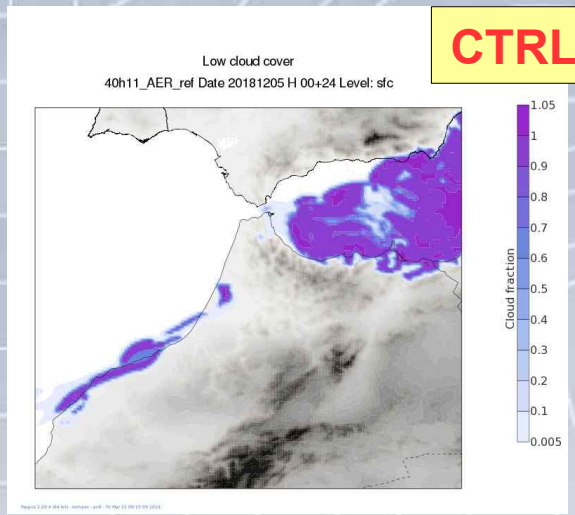


Formation of low clouds and fog at the NW coast of Morocco.

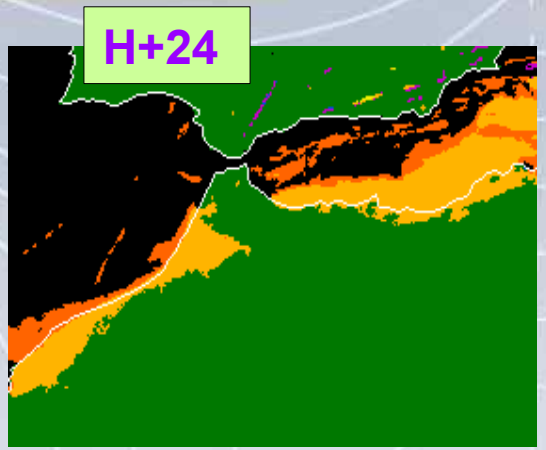
With the aerosols the fog starts earlier than with the control experiment but still not as soon as observed.

There are not too many differences when adding BC and OM

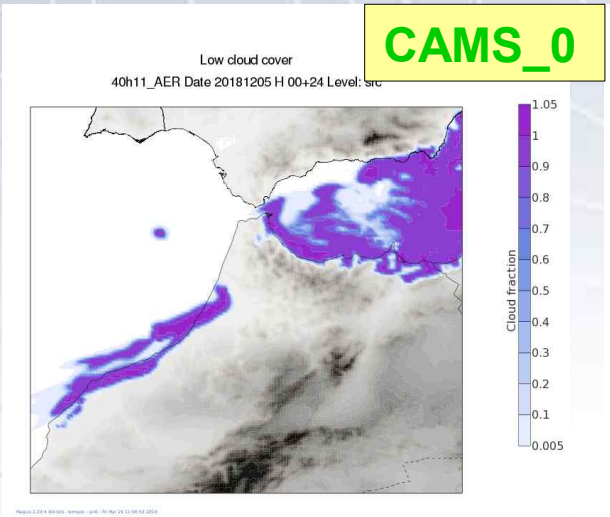
I.4. *Microphysics*. Effect on the clouds.

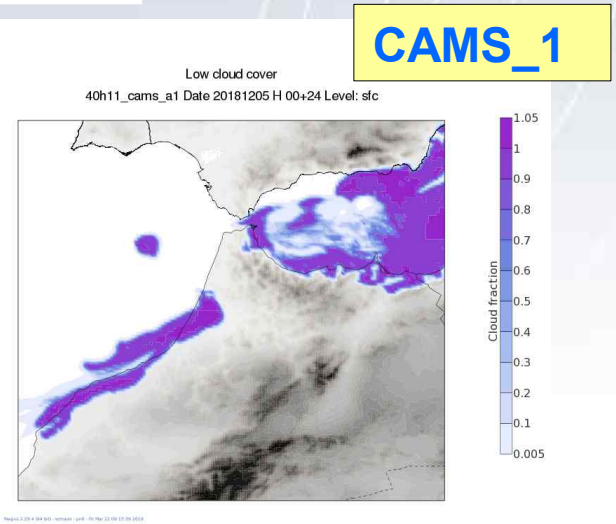


NW coast of Morocco.



Low cloud cover 05/12/2018 H+24

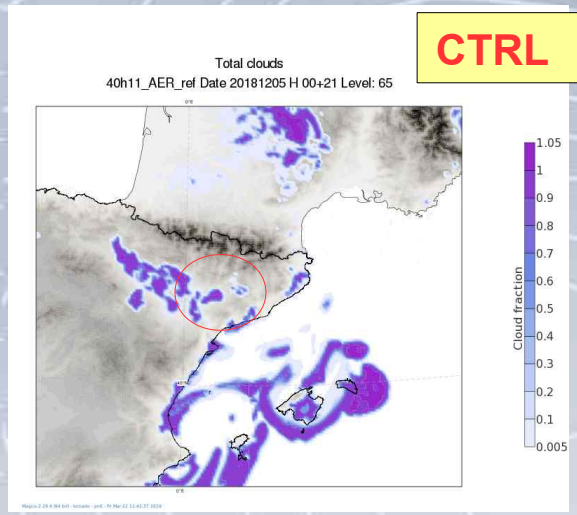


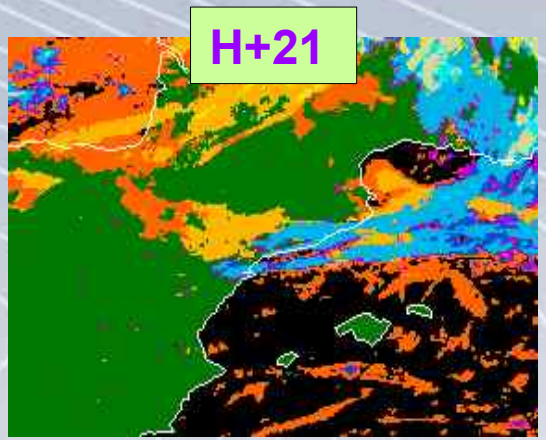


Formation of low clouds and fog at the NW coast of Morocco.

Small increment in the area of the fog when adding BC and OM.

I.4. *Microphysics*. Effect on the clouds.

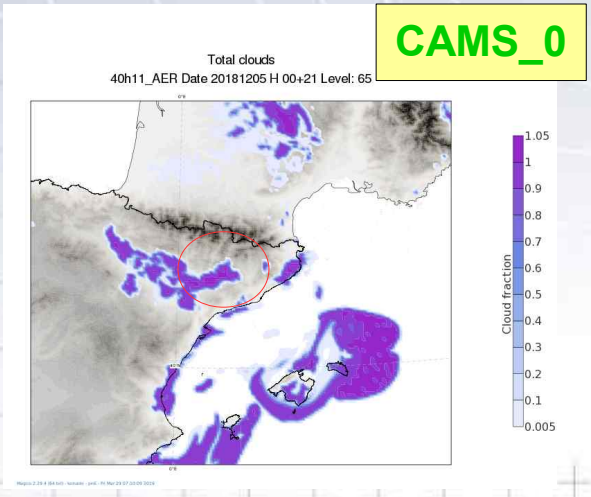


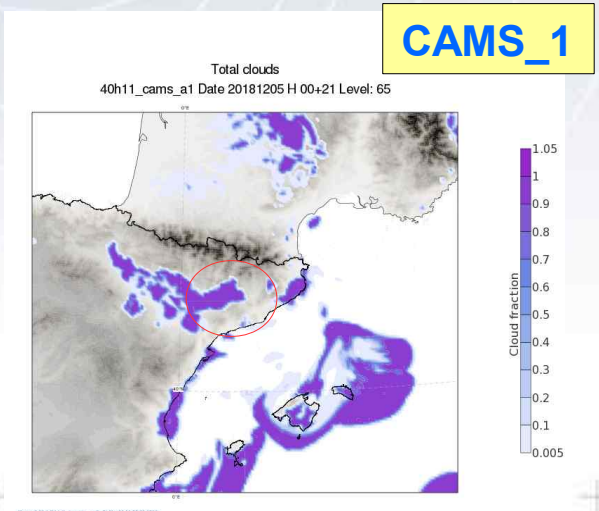


Over land with CAMS the fogs are larger.

Not too many differences when BC and OM are considered

Field: Fog (total clouds at level 65)
Date:05/12/2018 H+21

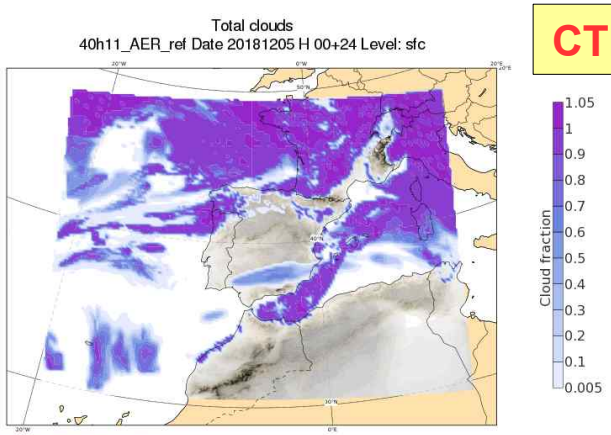




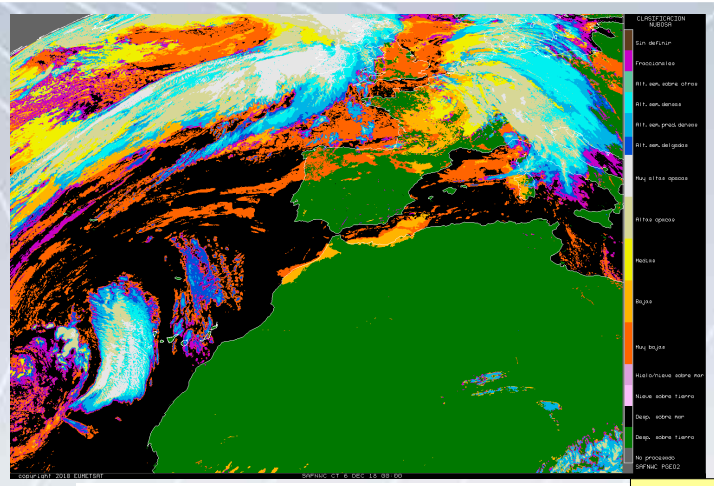
I.4. *Microphysics*. Effect on the clouds.

Fake fogs appear over the sea in front of the coast of Africa in this case.

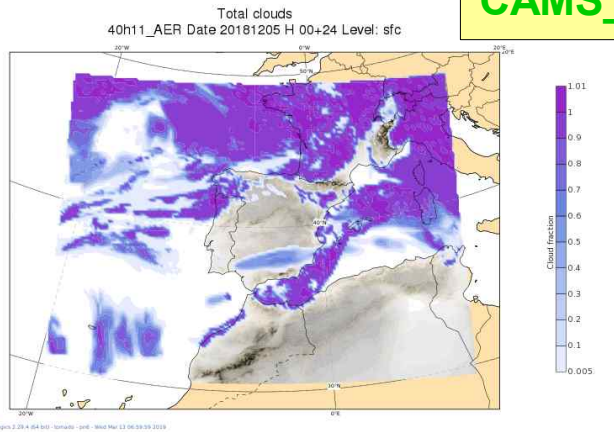
Although this problem is related with the microphysics and the CCN, that might not be the cause, and a different approach to solve it should be considered



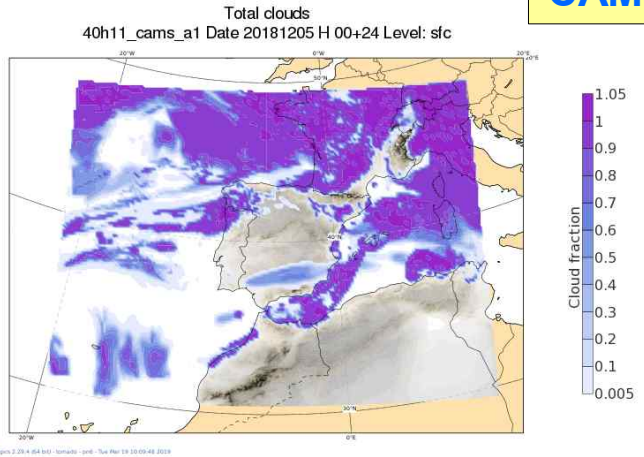
CTRL



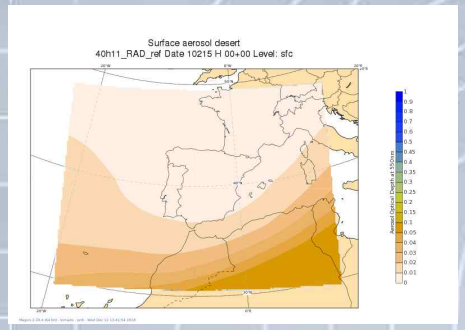
CAMS_1



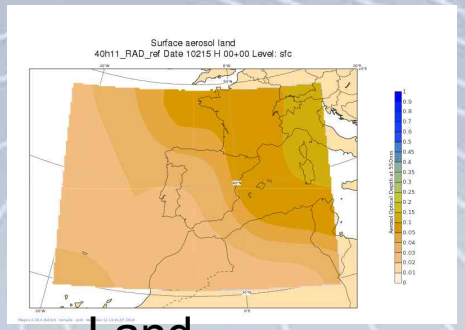
CAMS_0



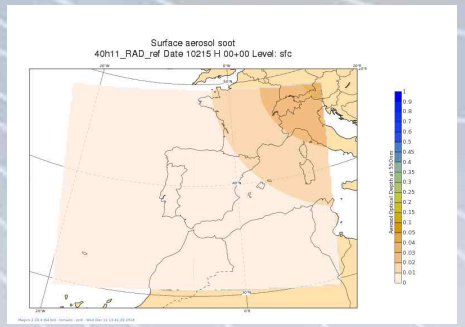
II.1. Radiation. Introduction. Obtention AOD



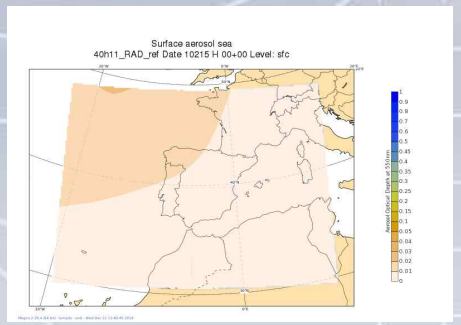
Desert



Land



Soot



Sea

Direct Short Wavelenght Radiation

In HARMONIE-AROME the direct radiative effects of aerosols consider:

CTRL

*AOD550 (SEA, LAND, SOOT, DESERT)surface fields initialized from climate FA file

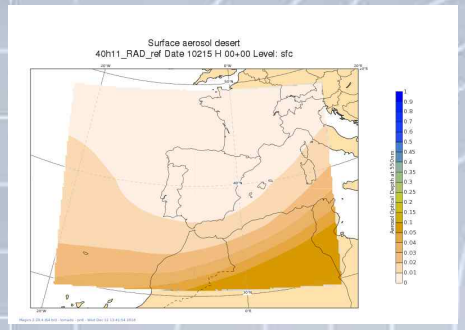
*Vertical distribution of AOD550 are prescribed and backgroud AOD values are added.

In order to consider the CAMS aerosols without introducing too many modifications in the code, the vertical distributions are calculated from the aerosol mixing ratio fields and a constant mass extincion coefficient for every aerosol specie. The distribution are added up to consider the 4 tegen species in the following way:

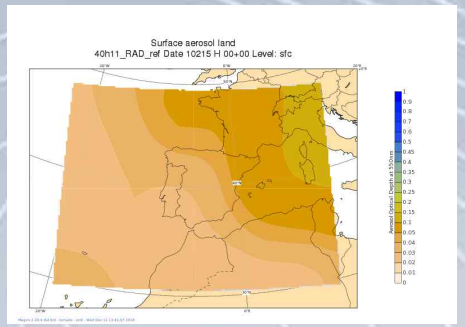
LAND = Sulfate(11) + Hydrophobic Organic matter(7) + Hydrophilic Organic Matter(8)
SEA = Sea salt(1) + Sea salt(2) + Sea salt(3)
DESERT = Desert dust(4) + Desert Dust(5) + Desert dust(6)
SOOT = Hydrophobic Black Carbon(9) + Hydrophilic Black Carbon(10)

This have been done copying and changing the routine radaer.F90

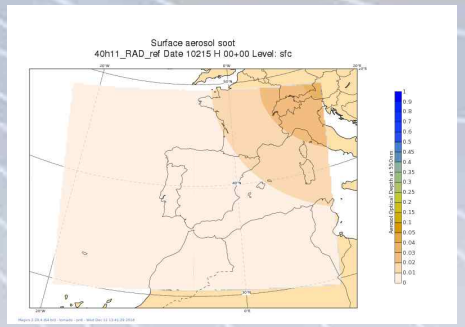
II.1. Radiation. Introduction. Obtention AOD



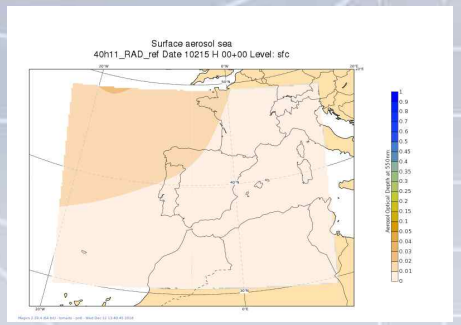
Desert



Land



Soot



Sea

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CAMS_1

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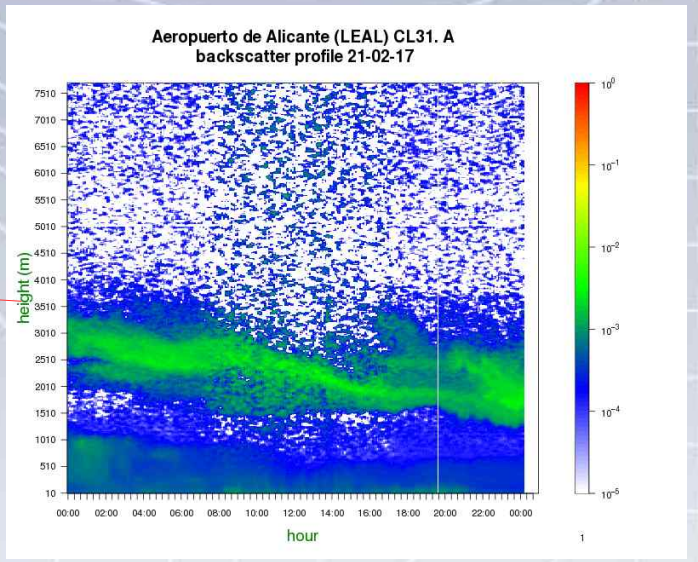
This have been done copying and changing the routine radaer.F90

II.2. Dust intrusion Case. February 2017

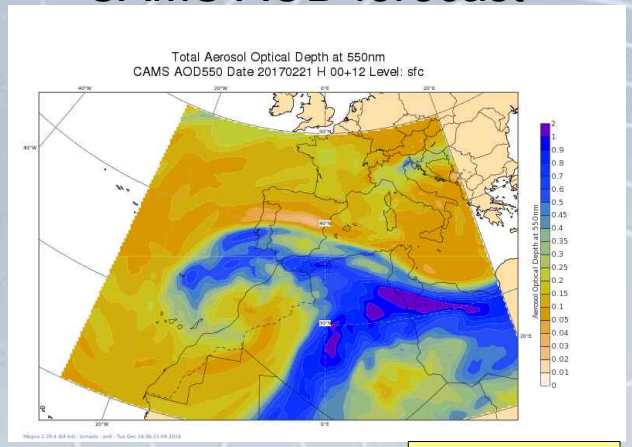


Snapshot of Backscatter profile. Ceilometer Vaisala CL31 at Alicante airport for 21/02/2017

https://earthobservatory.nasa.gov/images/89731/dust-storm-over-north-africa
On February 21, 2017, the Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi NPP satellite captured this natural-color image of a large dust plume streaming from North Africa toward Europe and the Atlantic Ocean.
NASA image by Jeff Schmaltz, LANCE/EOSDIS Rapid Response. Caption by Adam Voiland.

II.2. Dust intrusion Case. February 2017

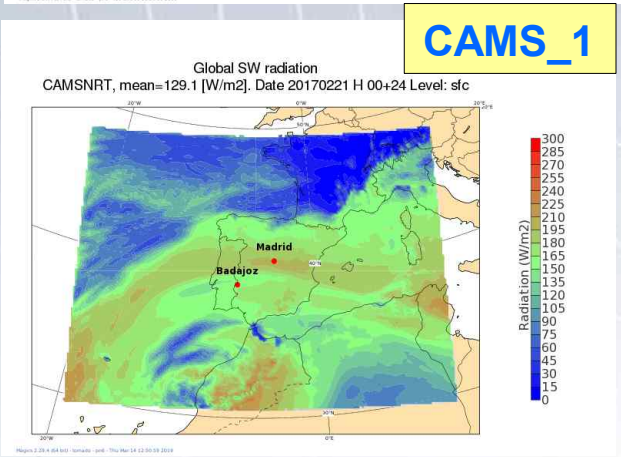
CAMS AOD forecast



In this case the dust is going to be the most significative element in the SW reduction at the surface.

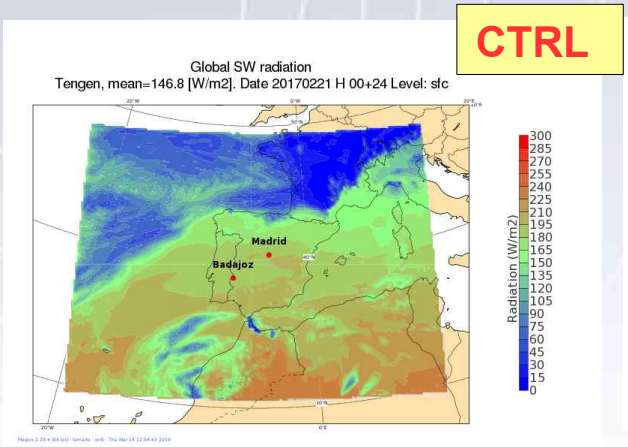
Significant difference in the SW radiation are obtained when the aerosol fields from CAMS are considered

CAMS_1

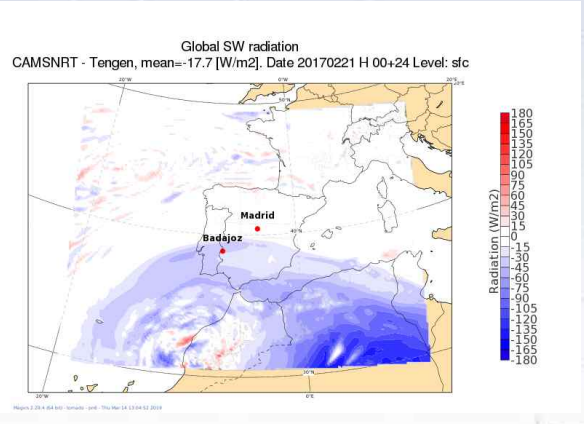


Global Short Wave radiance.
HARMONIE-AROME with
CAMS near real time aerosols

CTRL

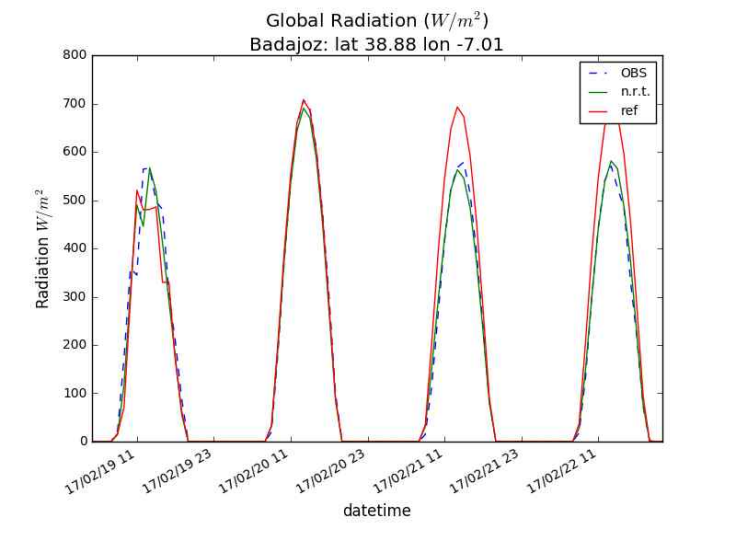


Global Short Wave radiance.
HARMONIE-AROME with
Climatic Tegen aerosols

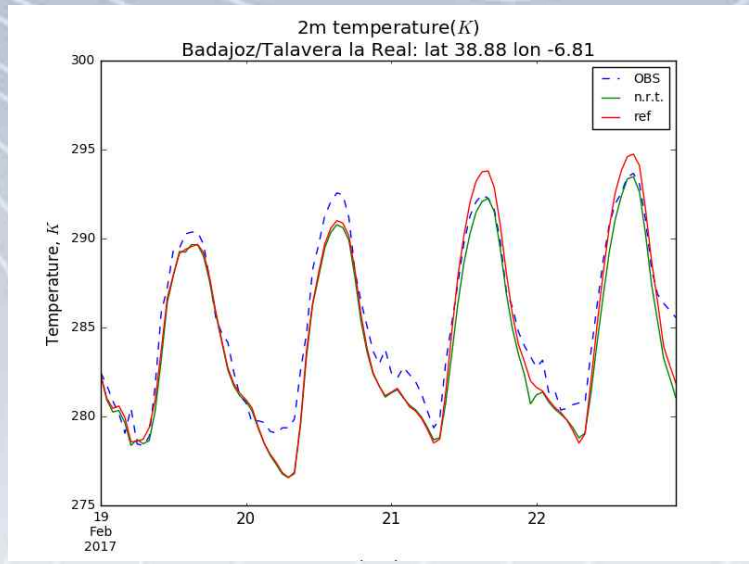


Difference

II.2. Dust intrusion Case. February 2017



Time plot Global radiation in **Badajoz station**. Joint plots of 24h forecasts for every day at 00 from 19/02/2017 until 22/02/2017



2m temperature. (The same as for Global radiation plot)

Observations- Blue Dashed line
Control experiment – red line
CAMS near real time aerosols – green line

The 2m temperature and the SW radiation when n.r.t. aerosols from CAMS are considered show much better agreement with the observation during daily hours.

Other issues

- Ocasionally high values of the aerosol MR after forecast lengths of 30 h.
- Code issues
  - Cy. 40h11: 9 new routines. Other 9 routines modified
    - At the local supercomputer in AEMET and at the ECMWF
    - Still no version uploaded to the repository
  - Cy. 43: Adaptation to this cycle not yet started
- Computational issues
  - Modification of memory limit in gl_bd:
    EC_memory_per_task was multiplied by 10
  - How much time does the forecast take compared with the control?
    Still not check
- Future work
  - Parametrization of the dry deposition, specially needed for dust (in progress)
  - Parametrization of the sea salt formation.
  - Introduce some modifications in the microphysical parametrization.
  - To consider the mass extinction dependence with the humidity.
  - Verification of the new configuration for microphysics and radiation.
  - New test cases of non observed fogs could be interesting

Conclusions

- Microphysics
  - Verification results showed that the introduction of CAMS aerosol may have a neutral or positive impact in the forecast of high precipitation
  - Despite of being modifying only the cloud condensation number concentration in the model, the test cases also showed that the introduction of aerosol produce an impact in the forecast of fog and high precipitation events.
  - A high number of CCN produce the appearence of fake fogs over the sea
  - Still it is needed a deeper knowledge of the aerosol size distribution.
  - Parametrization of dry deposition, sea salt formation should be the next step.
- Radiation
  - The inclusion of dust aerosols is very important to forecast the SW radiation and 2 m temperature during a dust event.
  - The introduccion of the dependence of the mass extinction with the humidity must be done.

GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA
AEMet
Agencia Estatal de Meteorología

Thank you for your attention !!