Use of CAMS aerosols in HARMONIE-AROME

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1st ACCORD All Staff Workshop

12 - 16 April, 2021

Outline

- Update of the use of CAMS aerosols in HARM-AROME.
- Examples of the impact of aerosols in forecast.
- Conclusions.

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CAMS aerosol fields

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".

The horizontal resolution of the CAMS Global data is ~40 km (T511L137) (it was T511L60 until 9/7/2019).

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".

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

paramId	shortName	name
210247	aermr16	Nitrate fine mode aerosol mass mixing ratio
210248	aermr17	Nitrate coarse mode aerosol mass mixing ratio
210249	aermr18	Ammonium aerosol mass mixing ratio

Aerosol species available since 9/7/2019

A setup of HARMONIE-AROME is being developed to use this aerosol fields in the microphysics and the radiation schemes.

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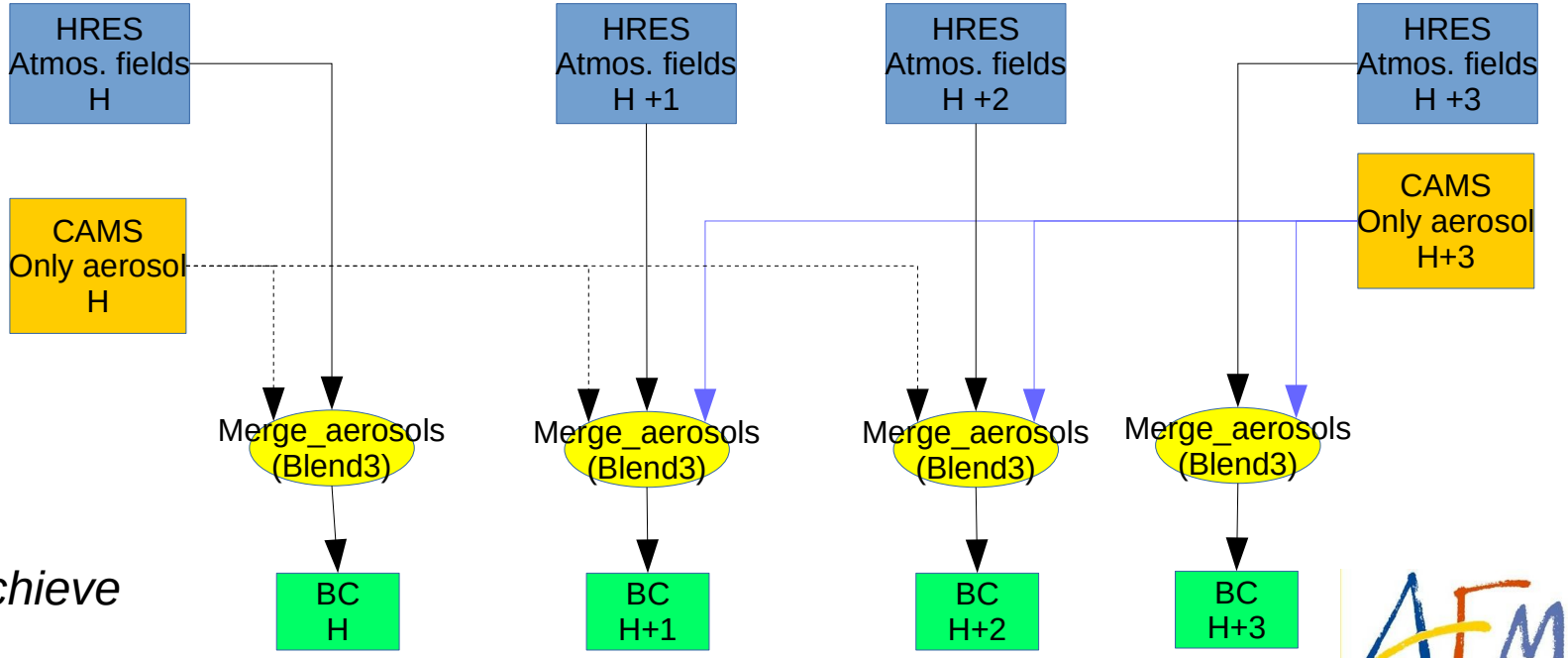
Aerosol in boundary conditions and first guess.

HRES	CAMS
atmospheric fields	aerosol fields (14)+ atmospheric fields needed for interpolation
Resolution (11km) 137 levels	Resolution (40km) 137 levels
every 1h	every 3h
grib format	grib format
name: fcYYYYMMDD_HH+FFF	name: aer_YYYYMMDD_HH+FFF

grib format
from MARS

FA
format



Ulf modified Blend3 to achieve this.

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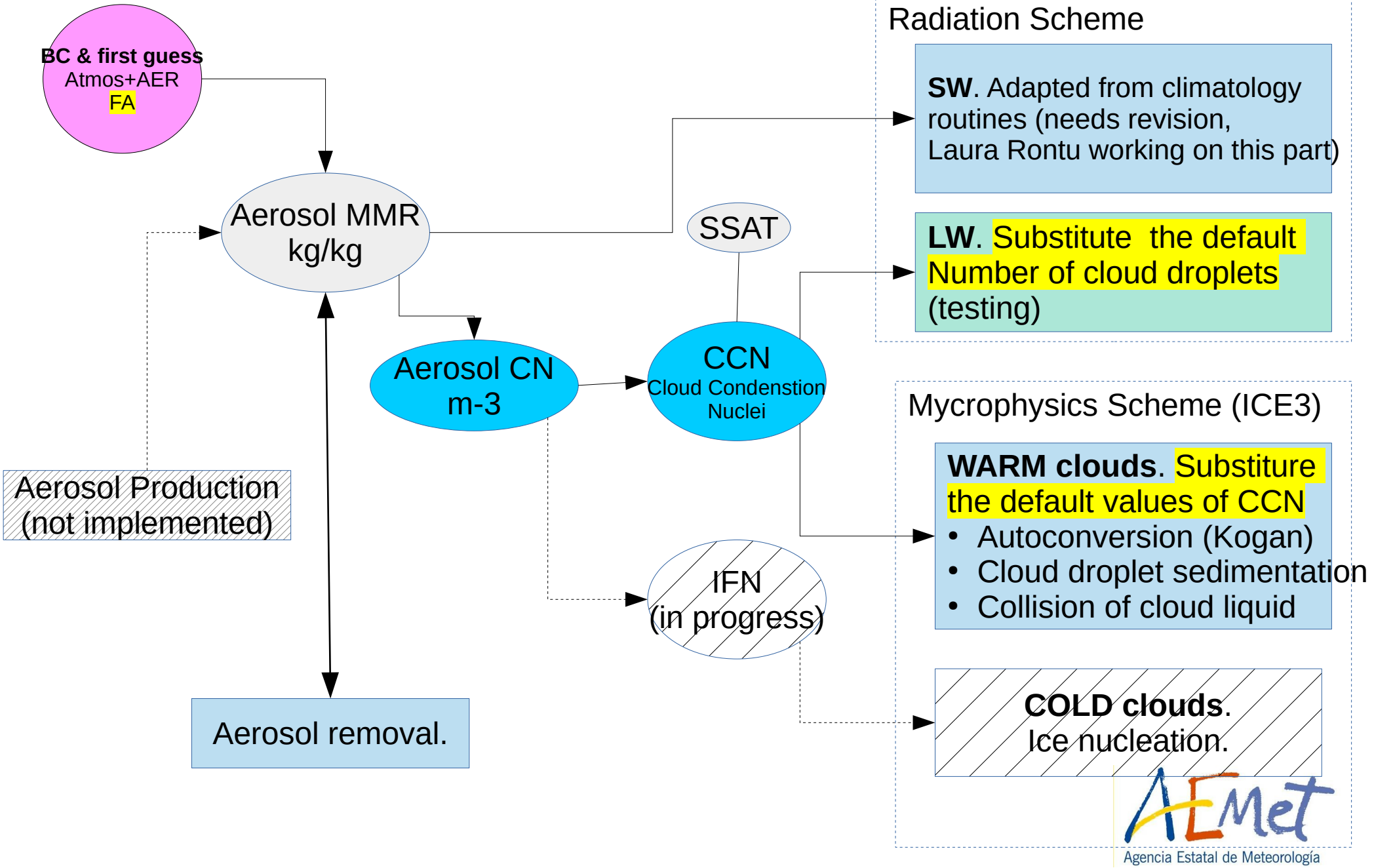
Flow scheme of aerosols in the code.



Impact of NRT aerosols on forecast

- Impact of ice nuclei on snow
- Radiation scheme: Dust intrusions.
- Fog case
- Precipitation case and verification.

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Ice nuclei parametrization

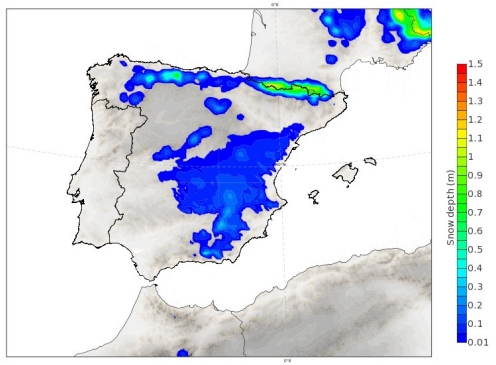
- Parametrization of Ice freezing nuclei (IFN) following DeMott et al., 2010
- Aerosols becoming ice nuclei: Desert dust (3 bins), hydrophobic Black Carbon and hydrophobic Organic Matter.
- Modifies ice nucleation in rain_ice.F90.

$$n_{\mathrm{IN},T_k} = a(273.16 - T_k)^b (n_{\mathrm{aer},0.5})^{(c(273.16-T_k)+d)},$$

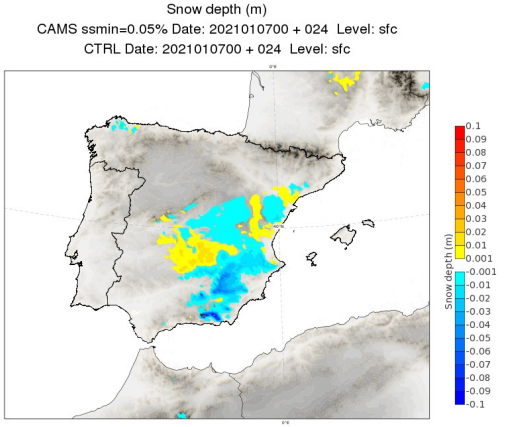
Test case. Impact on the accumulated snow:

Snow depth compared with control experiment shows an increment when Ice nuclei are considered.

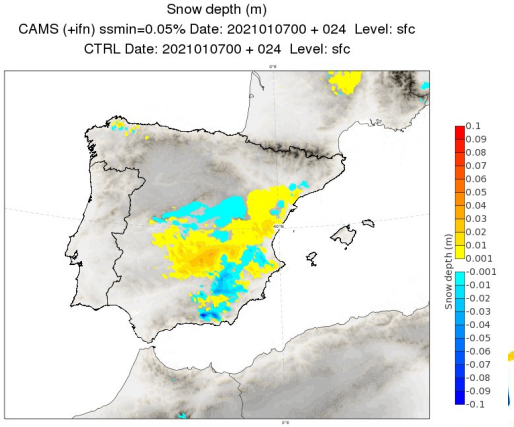
CTRL



CAMS - CTRL



CAMS(+ifn) - CTRL



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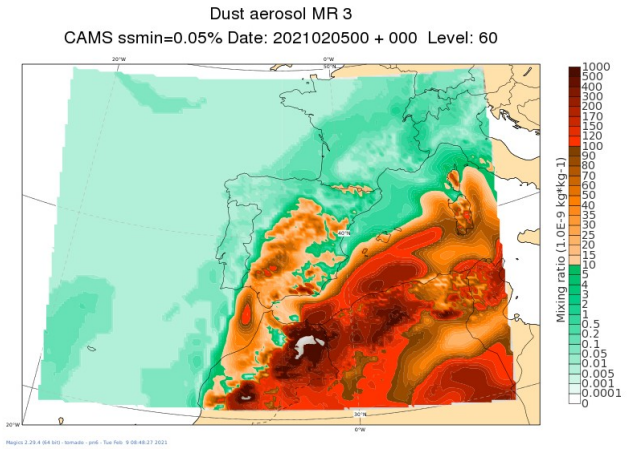
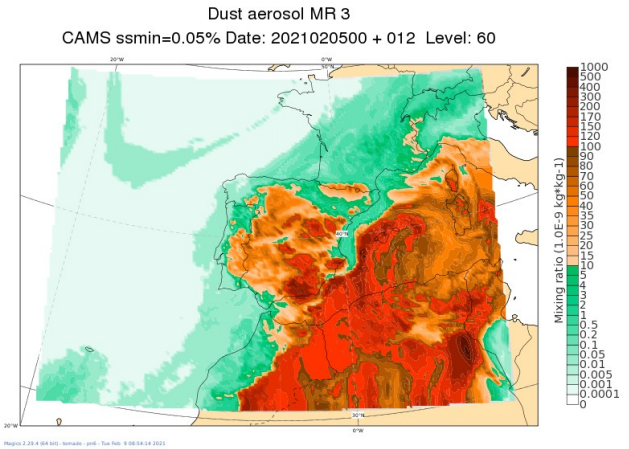
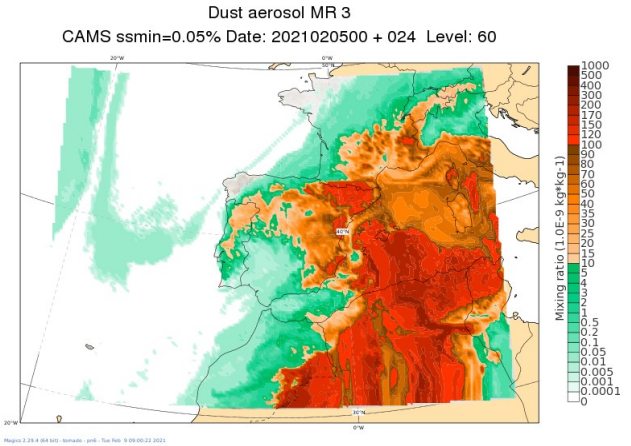
Dust intrusion case 05/02/2021



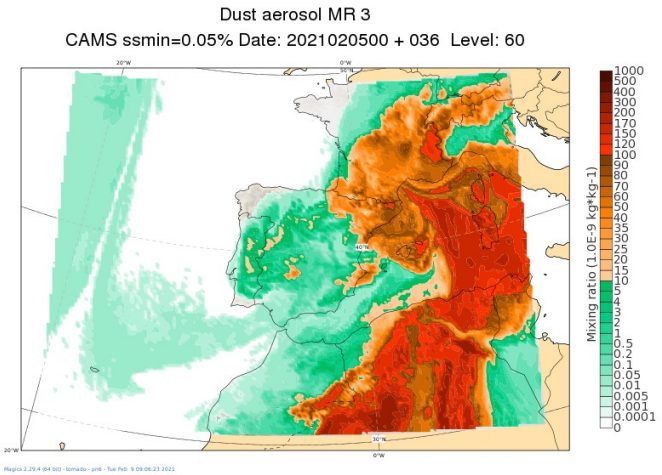




On the 5th of February 2021 there was a dust event affecting the Mediterranean and reaching high latitudes in Europe.

Two HARMONIE-AROME (cy. 43) experiments were run:
HA-CAMS: H-A + CAMS aerosols:
HA-CTRL: H-A (Control)

Date: 2021020500 HH+36



These plots show the evolution of the Mass mixing ratio of desert dust bin 3 (AEROMMR.DD3: 0.9-30 microns) at model level 60. (around 150 m. height) from experiment HA-CAMS.

Forecast length: 00, 12, 24, 36.

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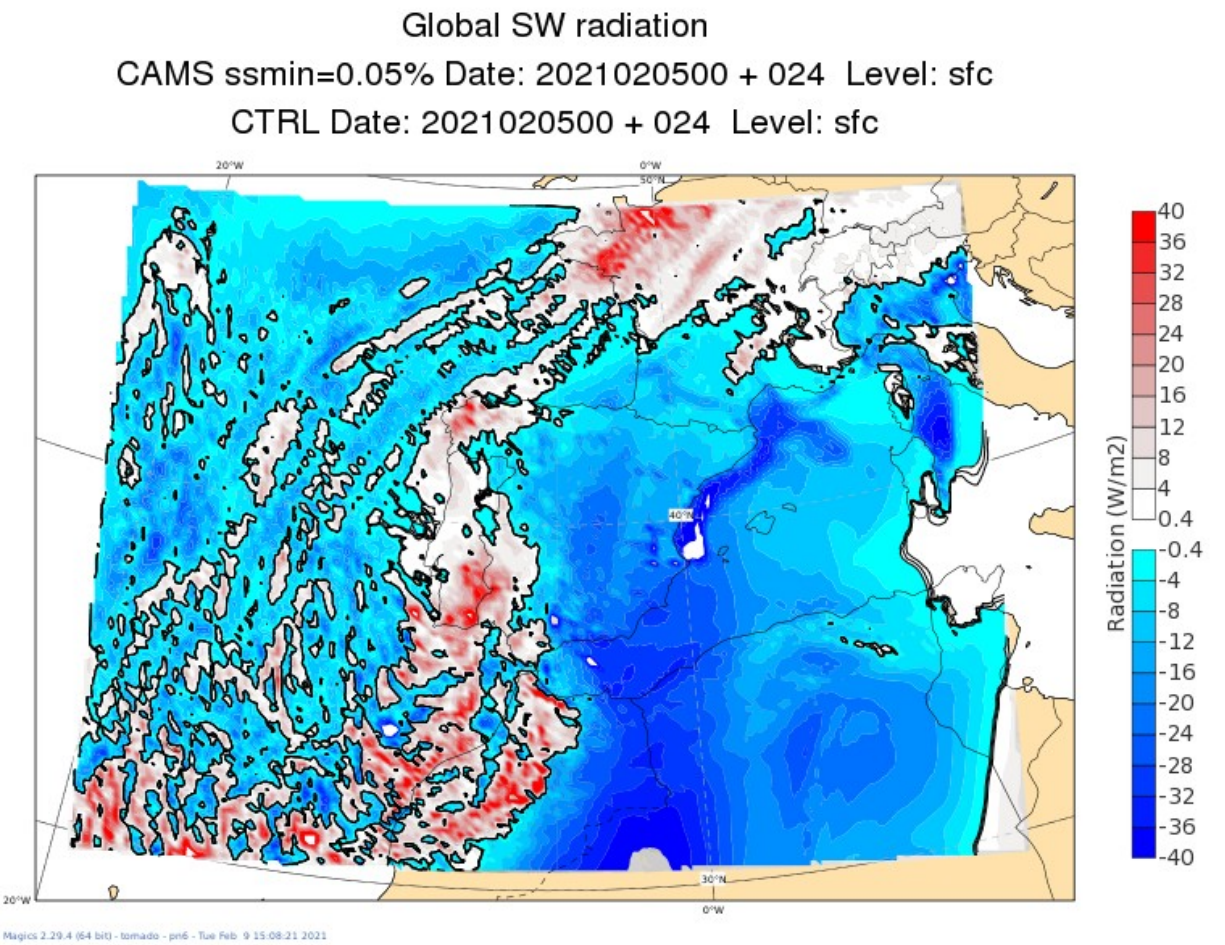
Dust intrusion case 05/02/2021

24 hours accumulated global radiation difference:

HARMONIE-AROME:
CAMS -CTRL

The blue area on the right of the figure shows the reduction in the global radiation when dust is taken into the model.

The differences to the west of Spain are due to different cloud distribution between both experiments.



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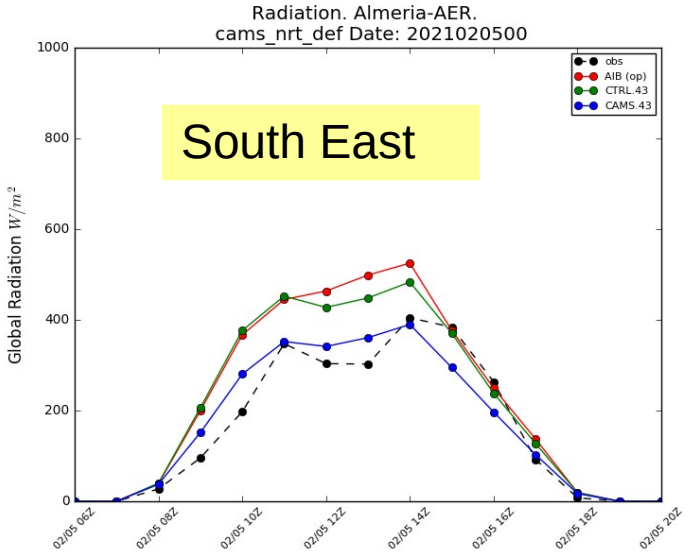
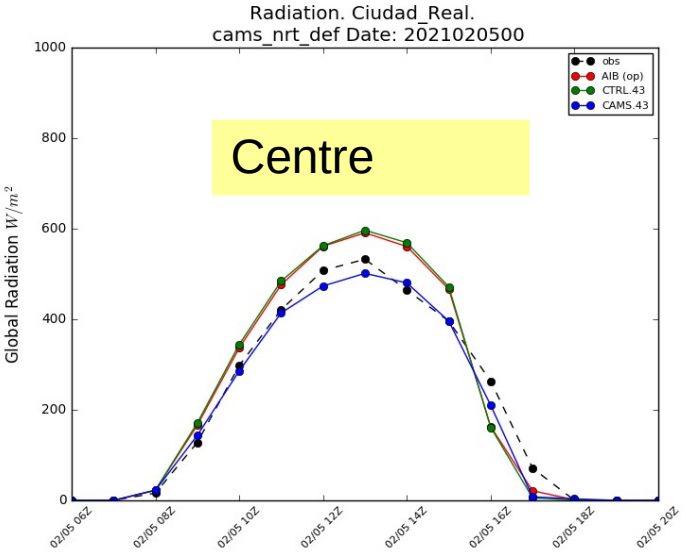
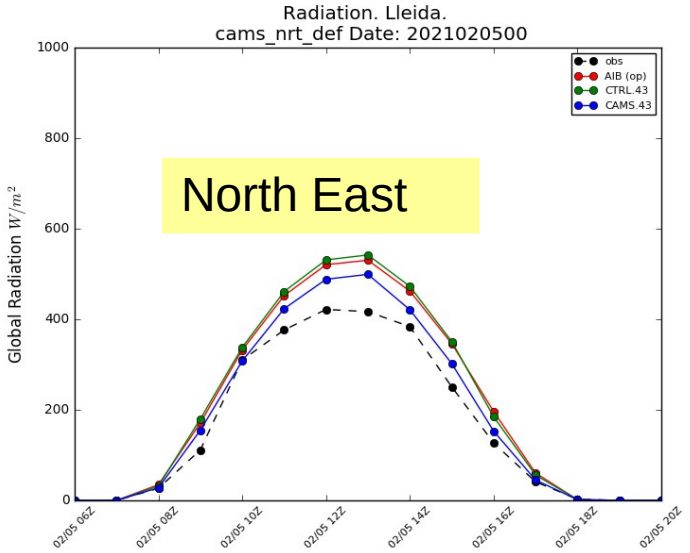
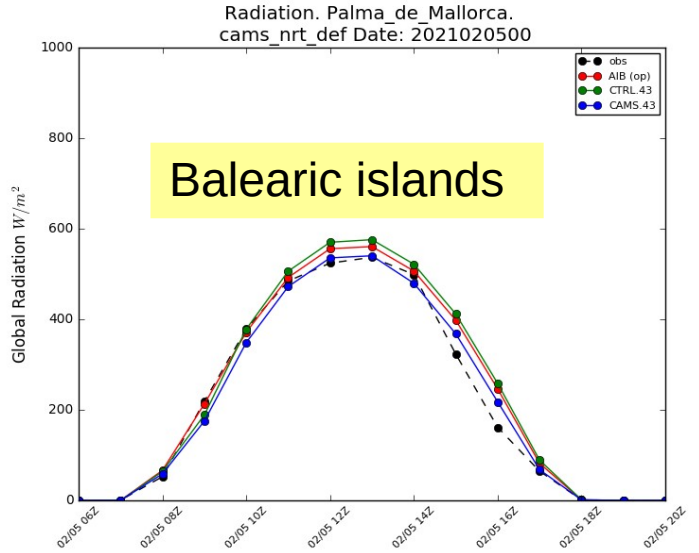
Dust intrusion case 05/02/2021









Hourly Global radiation
Model vs observations

Black: observation
Red: AIB (operational)
Green: 43 (ctrl)
Blue: 43 (CAMS)

Date: 2021020500

Four stations have been selected.

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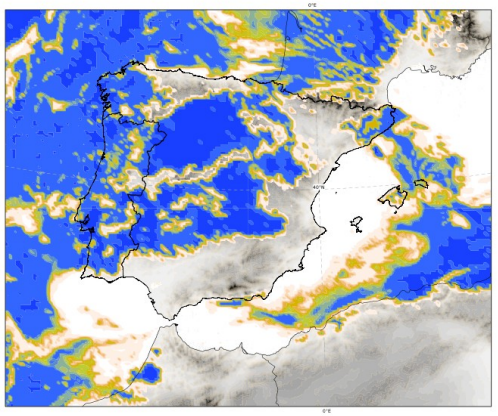
Fog case 14/02/2020

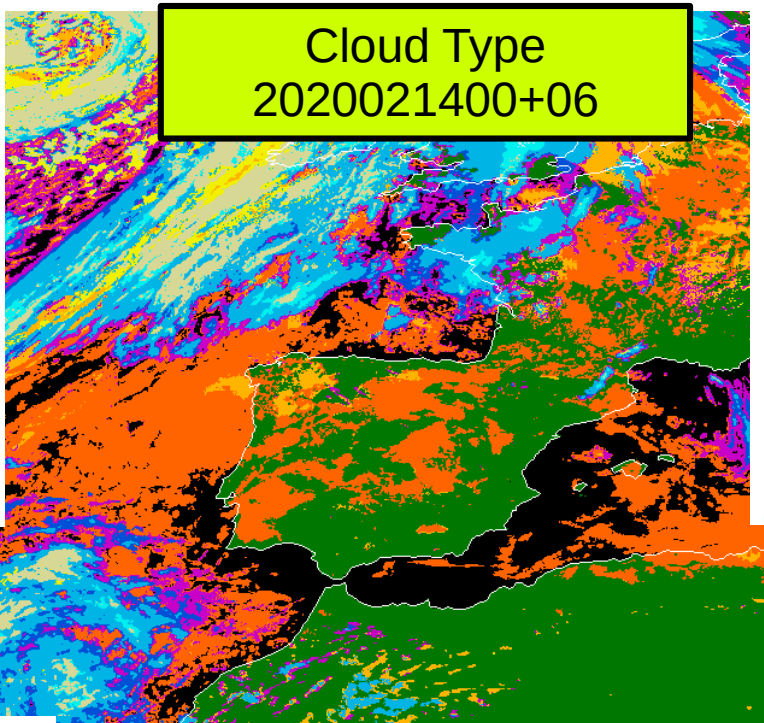
The EUMETSAT Network of Satellite Application Facilities

NWC SAF
Support to Nowcasting and Very Short Range Forecasting

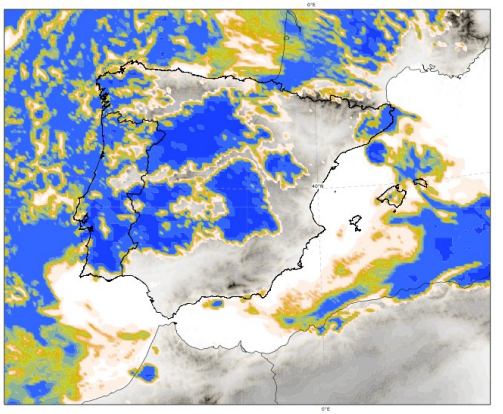
CTRL.lcc



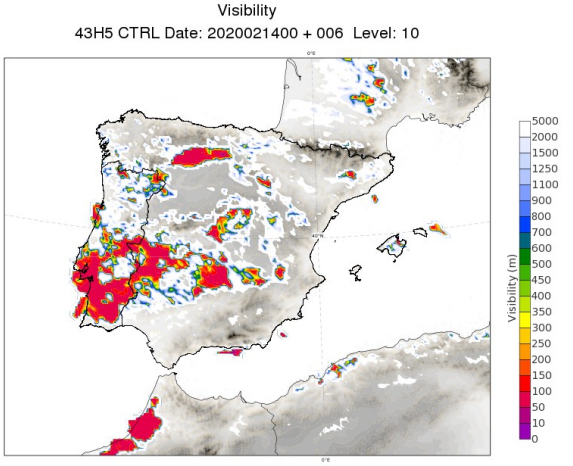
Cloud Type
2020021400+06



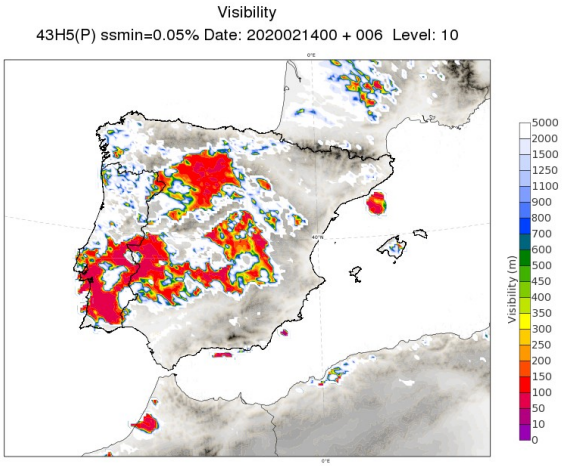
CAMS. lcc



CTRL. Visibility



CAMS. Visibility



Developing phase:
Similar lcc, but the visibility is different specially in the northern plateau

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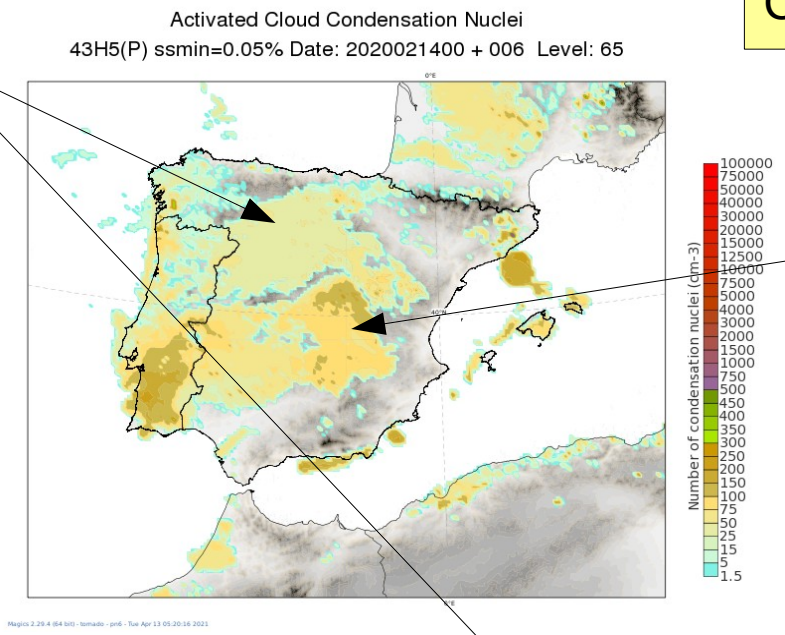
Fog case 14/02/2020

Northern plateau:
Low CCN number concentration (around 50 cm-3)

*A lower number of CCN in the northern plateau favoured the formation of fog.

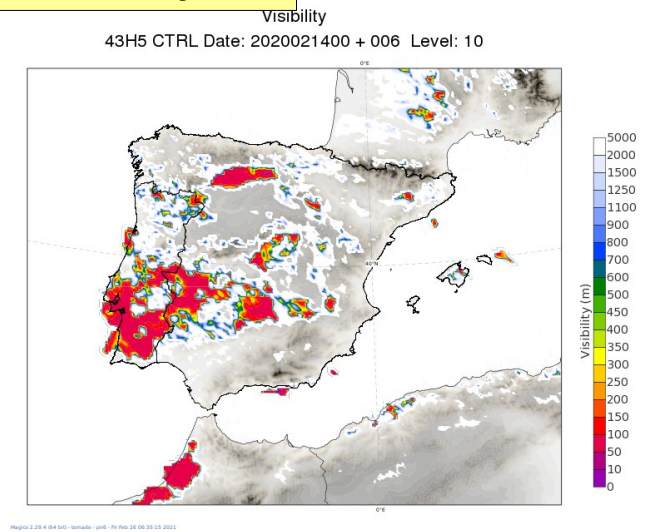
*In the southern plateau the differences are not so significative.

CAMS. CCN level 65

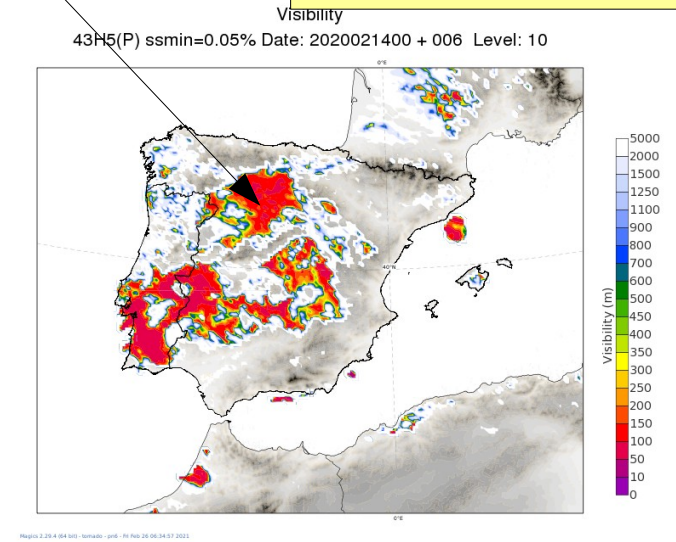


Southern plateau:
CCN number concentration around 100 cm-3. Less

CTRL.Visibility

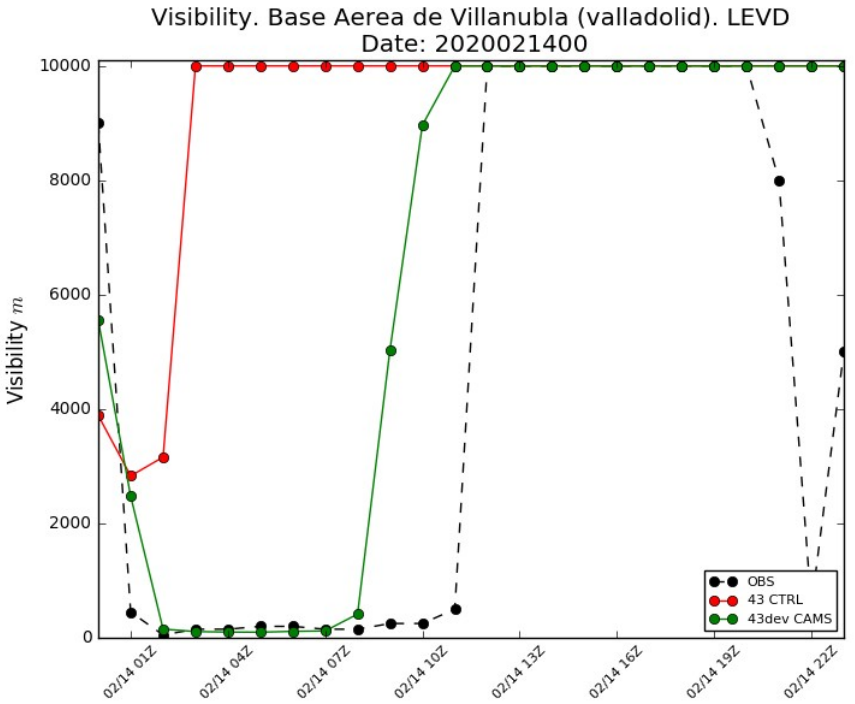


CAMS.Visibility

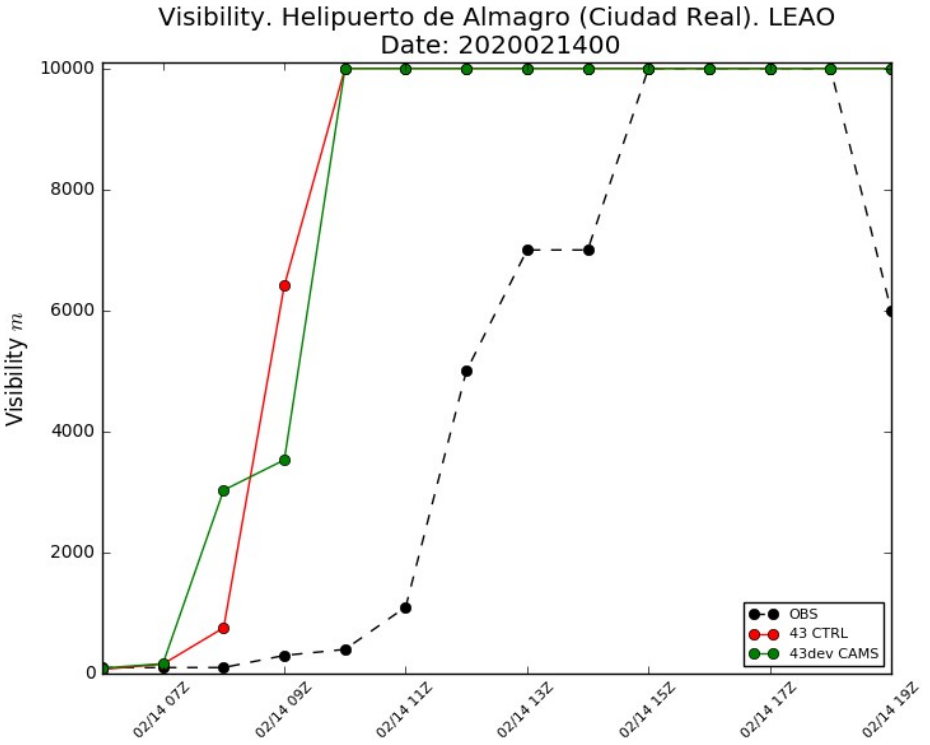


Fog case 14/02/2020

NORTH



CENTER



Visibility
Red: CTRL
Green: CAMS aerosols
Black: observation from METAR

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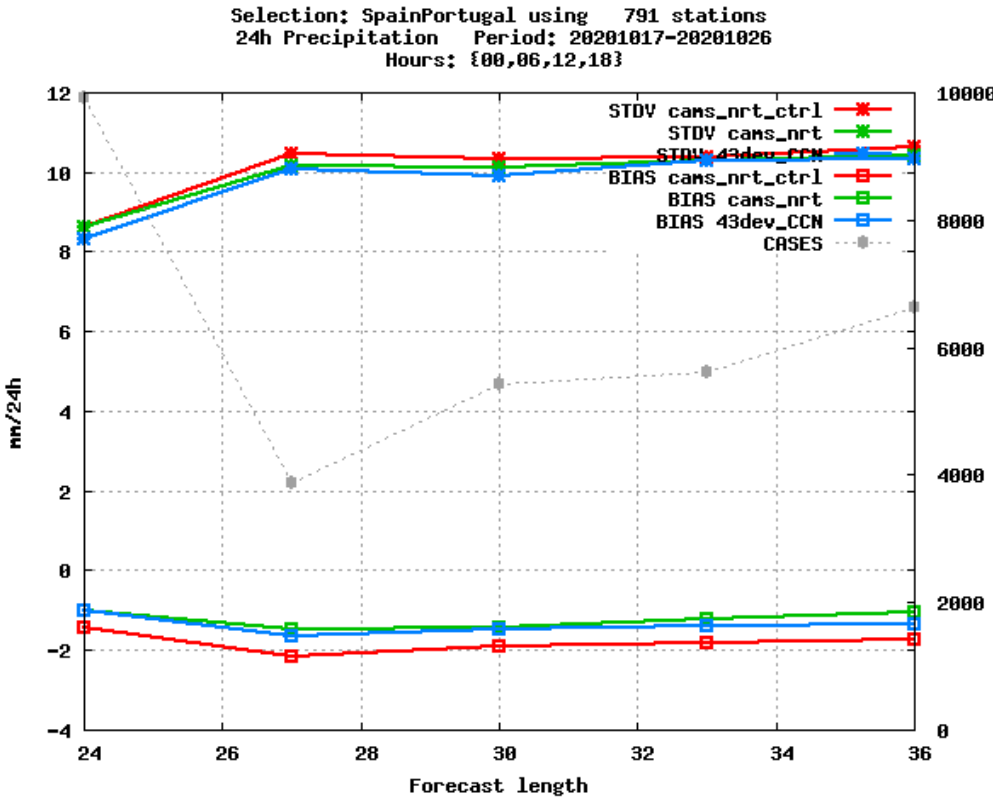
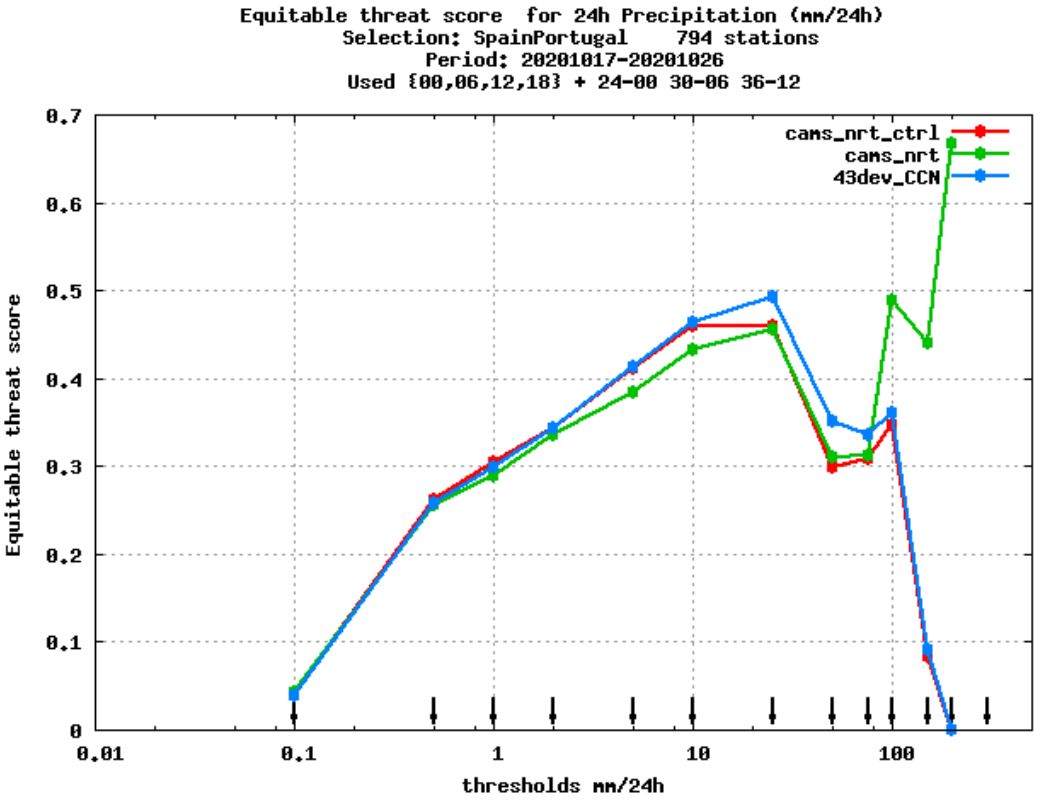
10 days verification (oct. 2020)

BIAS & STDV vs. Forecast length

24H Precipitation

ETS vs. thresholds





10 days verification:
17/10/2020-26/10/2020
24H precipitation
Red: CTRL
Green: CAMS aerosols
Blue: CCN modified to 75cm-3 & vertical dependence (Not the same commit as CAMS and CTRL)

The forecast of high precipitation events is much better when NRT (near real time) aerosols are used, but it is worse in the range between 1 and 15 mm/25h.
In the case of CCN=75 the ETS is better but not for extreme cases.

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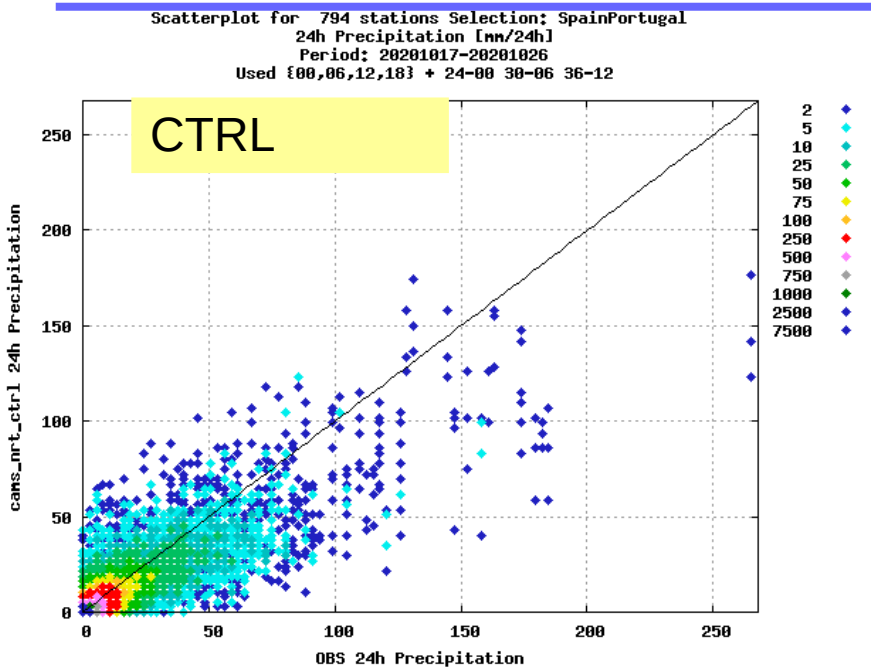
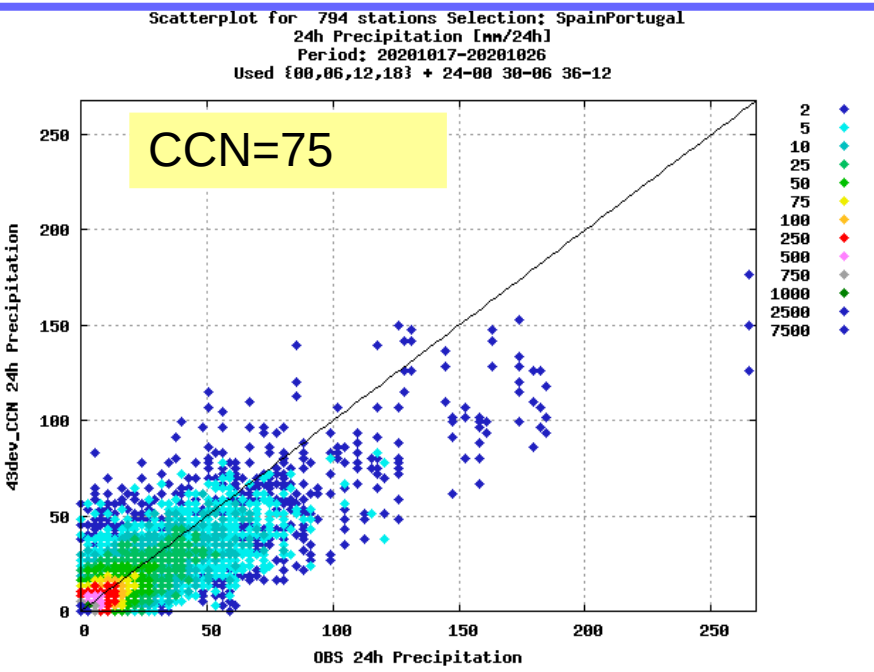
10 days verification (oct. 2020)

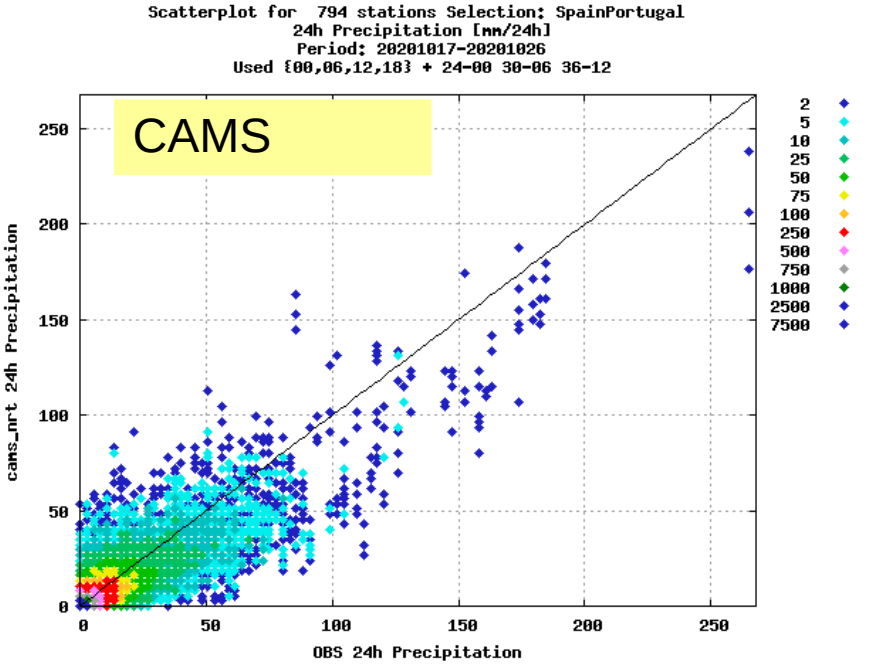




10 days verification:
17/10/2020-26/10/2020
24H precipitation.

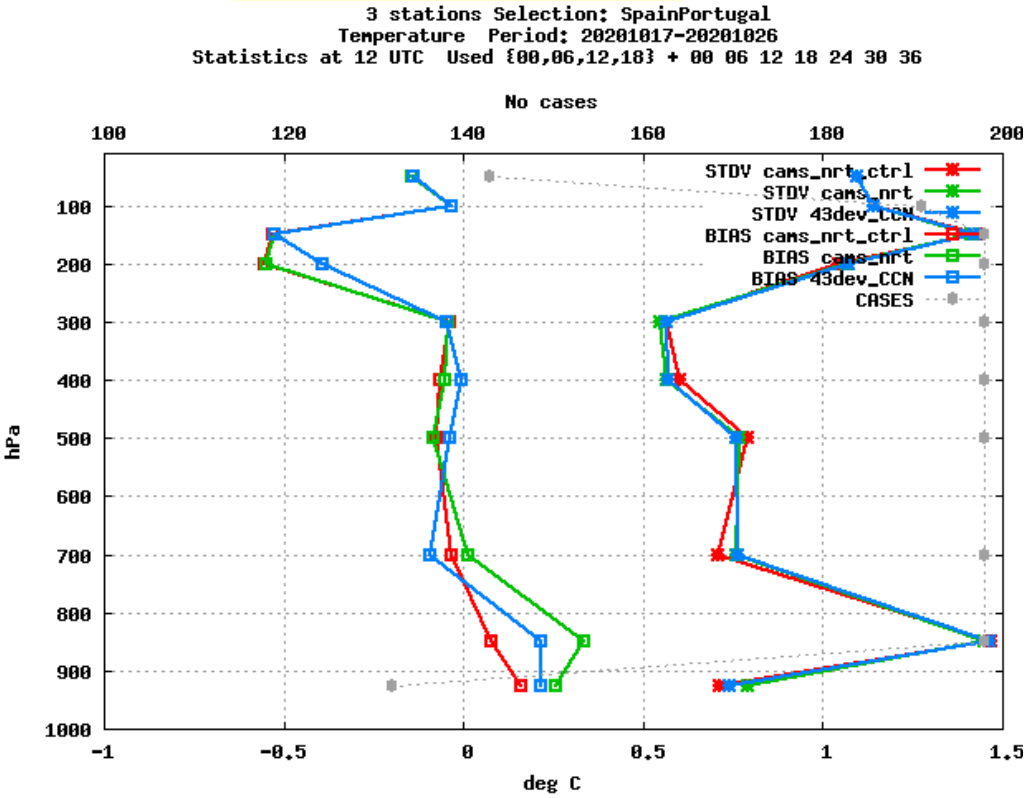
Scatter plots.

Although with CCN=75cm-3 there is an improvement, the best fit for high precipitation values corresponds to CAMS aerosols.

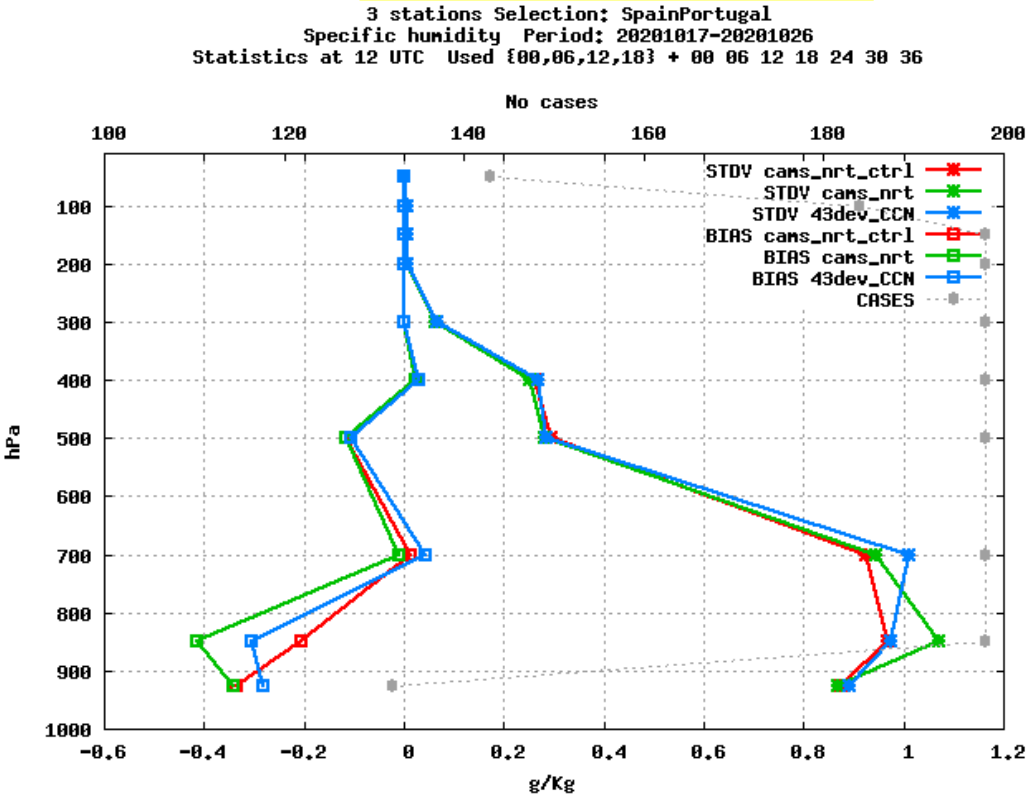


10 days verification (oct. 2020)

TEMPERATURE



SPECIFIC HUMIDITY



10 days verification:
17/10/2020-26/10/2020
24H precipitation
Red: **CTRL**
Green: **CAMS aerosols**
Blue: **CCN modified to 75cm-3**
& vertical dependence
(Not the same commit)

With NRT aerosols the atmosphere gets warmer and dryer. (also for CCN=75, but not so much)

Modifications in physical parametrizations might be needed

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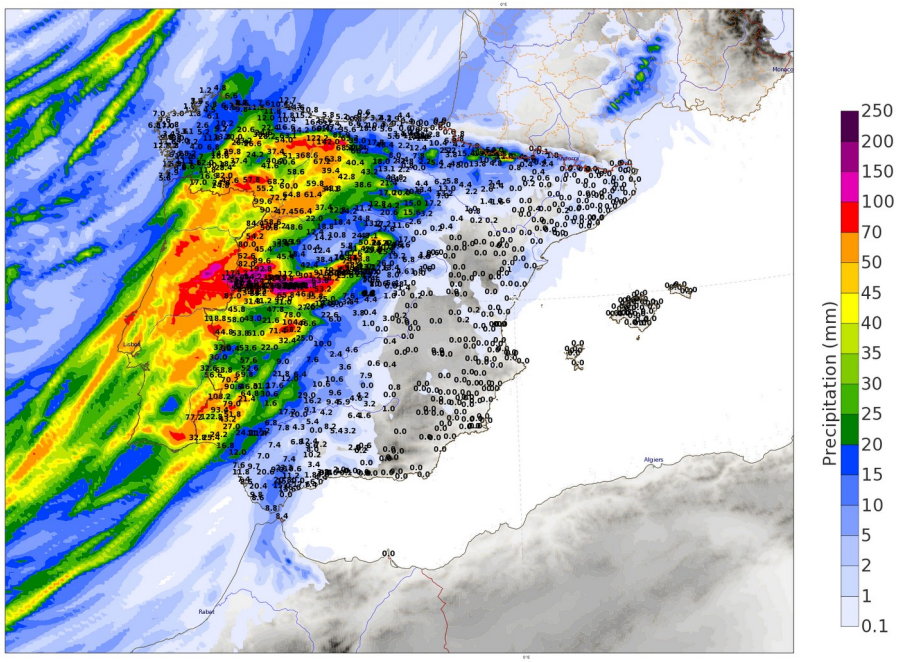
Precipitation case 20/10/2020

CAMS

Accumulated rain (mm/24h)

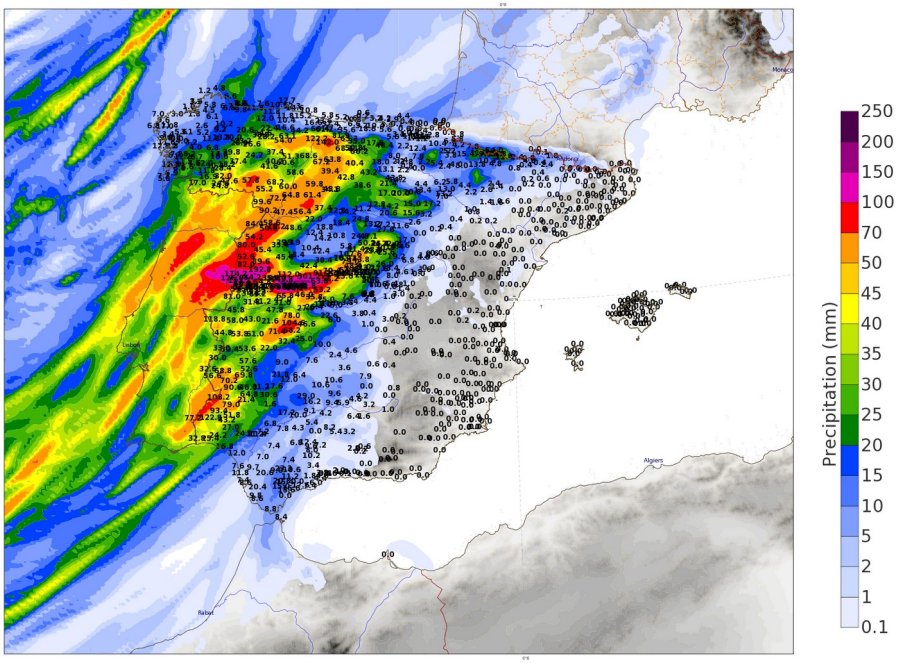
CAMS ssmin=0.05% Date: 2020102000 + 024 Level: sfc



CTRL

Accumulated rain (mm/24h)

CTRL Date: 2020102000 + 024 Level: sfc



24h accumulated precipitation.

CAMS: Increase of precipitation over mountain ranges and precipitation in the NE where it's not observed.

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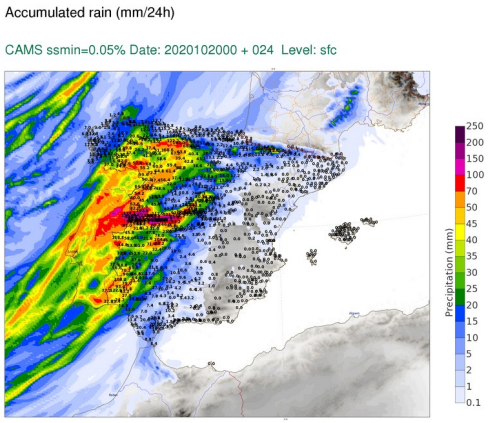
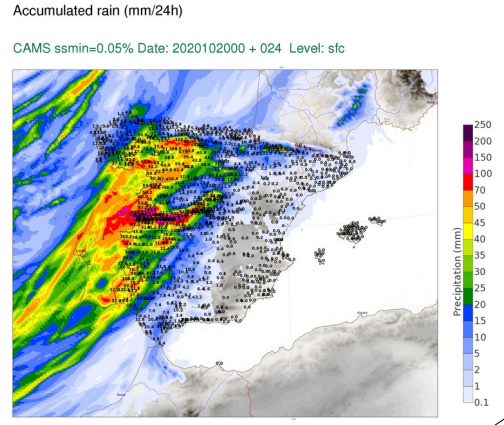
Precipitation case 20/10/2020

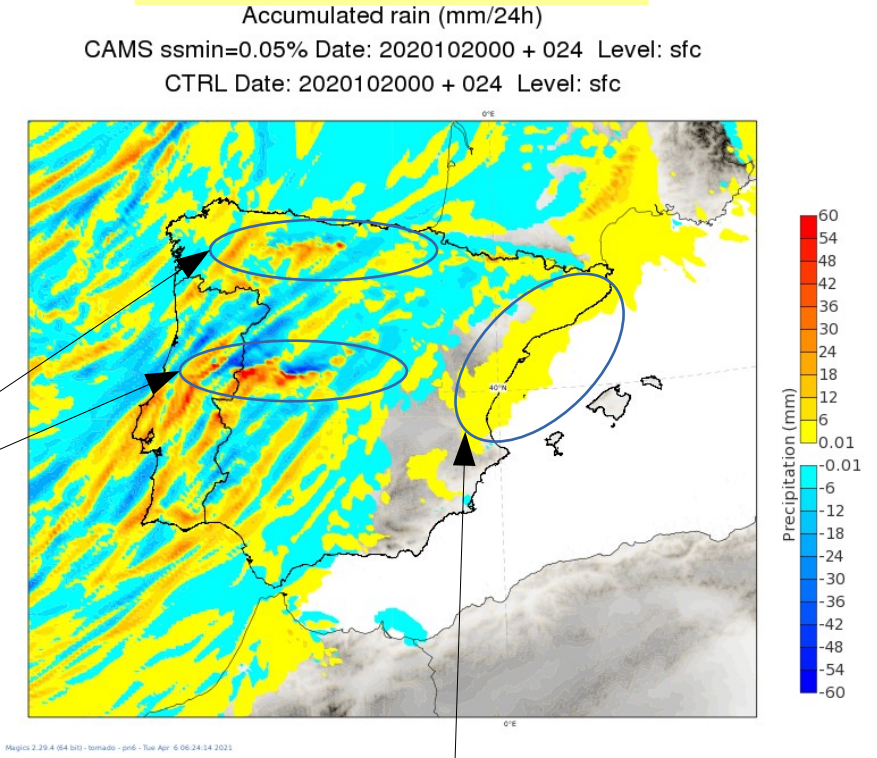
CAMS

CTRL

CAMS-CTRL







Increase of precipitation over mountain ranges.

24h accumulated precipitation difference: CAMS-CTRL.

Which microphysical parametrization is responsible of these differences?

Precipitation not observed in the NE and forecasted with nrt aerosols

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Microphysics

In order to know the impact of every parametrization on the precipitation, three experiments were run activating only one of the parametrizations each time with CAMS aerosols.

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

- **Autoconversion (cloud droplets → rain droplets) (Kogan. LKOGAN=TRUE)**

  It is the main responsible for the increase of precipitation in high precipitation cases and also in areas where no precipitation is expected.
- **Cloud droplet sedimentation.**

  It has low skills for high precipitation values.
- **Collision of cloud liquid.**

  Good behaviour in general.

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Microphysics. Autoconversion

Autoconversion

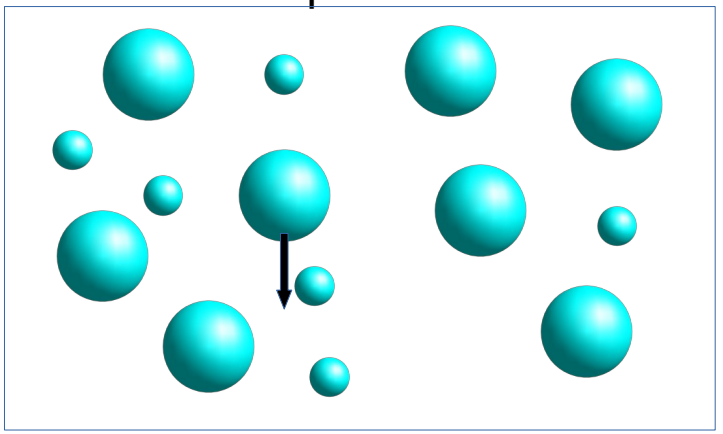
"The autoconversion is a process of "self-collection" of the particles within the same fraction or size category [cloud droplets], which transfers them into the next size category [raindrops]" (Khrovstyanov and Curry, 2014)

Kogan parametrization.

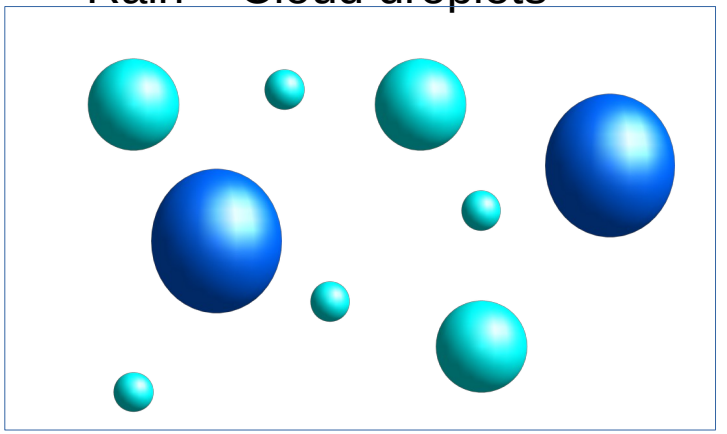
$$\left(\frac{\partial q_r}{\partial t}\right)_{auto} = 1350\, q_c^{2.47}\, N_c^{-1.79}$$

- qr: rain mass mixing ratio
- qc: cloud water mass mixing ratio
- Nc: Number of cloud droplets

Cloud droplets



Rain + Cloud droplets



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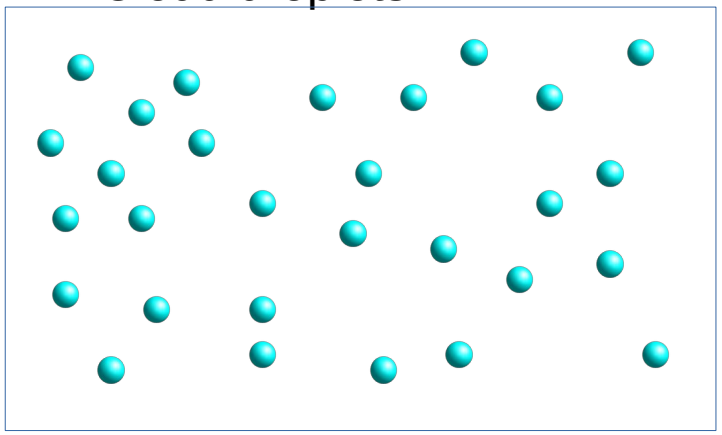
Microphysics. Autoconversion

Autoconversion

Kogan parametrization. The autoconversion rate is inversely proportional to Nc, so a low number of droplets will increase the autoconversion rate even though the humidity might be not too high.

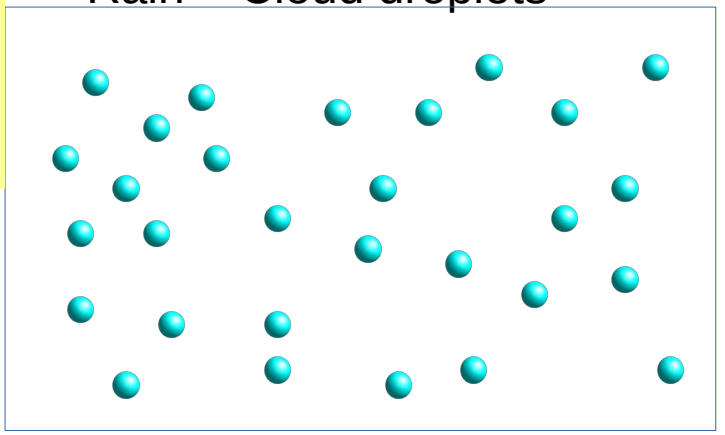
$$\left(\frac{\partial q_r}{\partial t}\right)_{auto} = 1350\, q_c^{2.47} N_c^{-1.79}$$

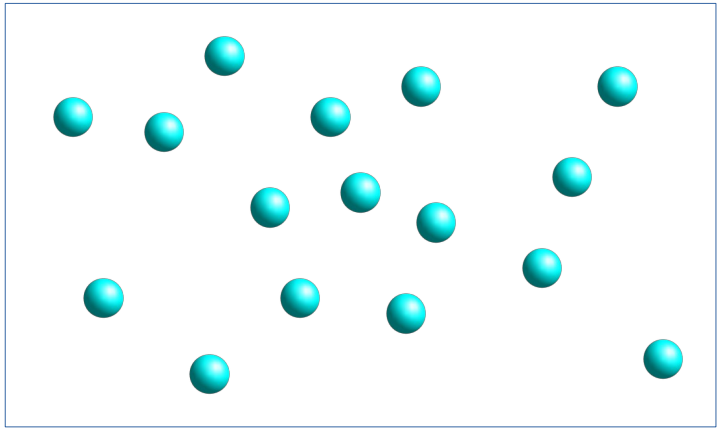
Cloud droplets



- CTRL: High cloud droplet number concentration.
- Default value: 300 cm-3 over land.
- The autoconversion rate will be small, no rain drops.

Rain + Cloud droplets





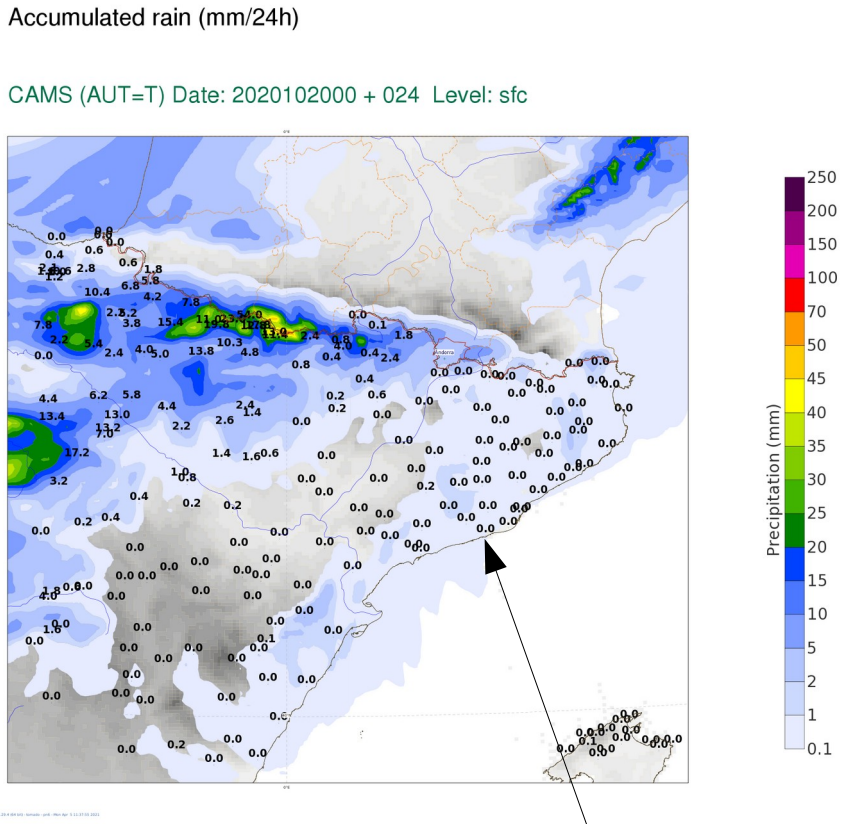
- CAMS: Lower cloud droplet concentration.
- Autoconversion rate will be higher and raindrops will be formed
- The resulting distribution might not be realistic!!!

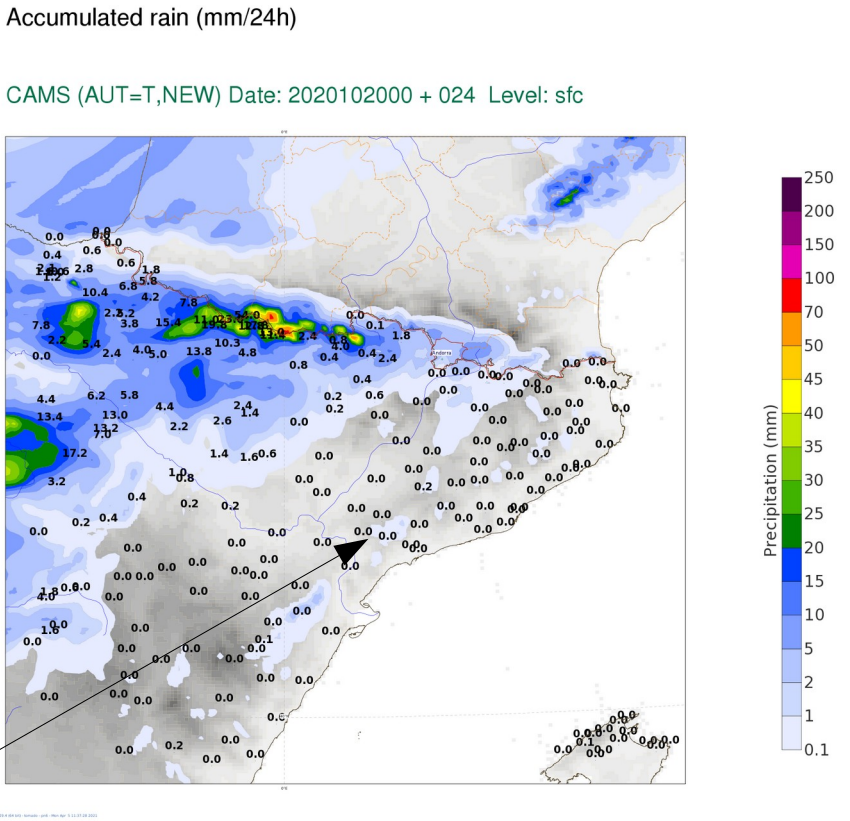
AUTOCONVERSION SHOULDN'T BE PERMITTED:
LIMIT TO AUTOCONV. ACTIVATION:
Droplet Radius > 20 micrometers

Microphysics. Autoconversion. Precipitation case 20/10/2020

CAMS. No-Corrected Autoconversion

CAMS. Corrected Autoconversion





24h accumulated precipitation.

Forecast improved in areas with no precipitation observed.

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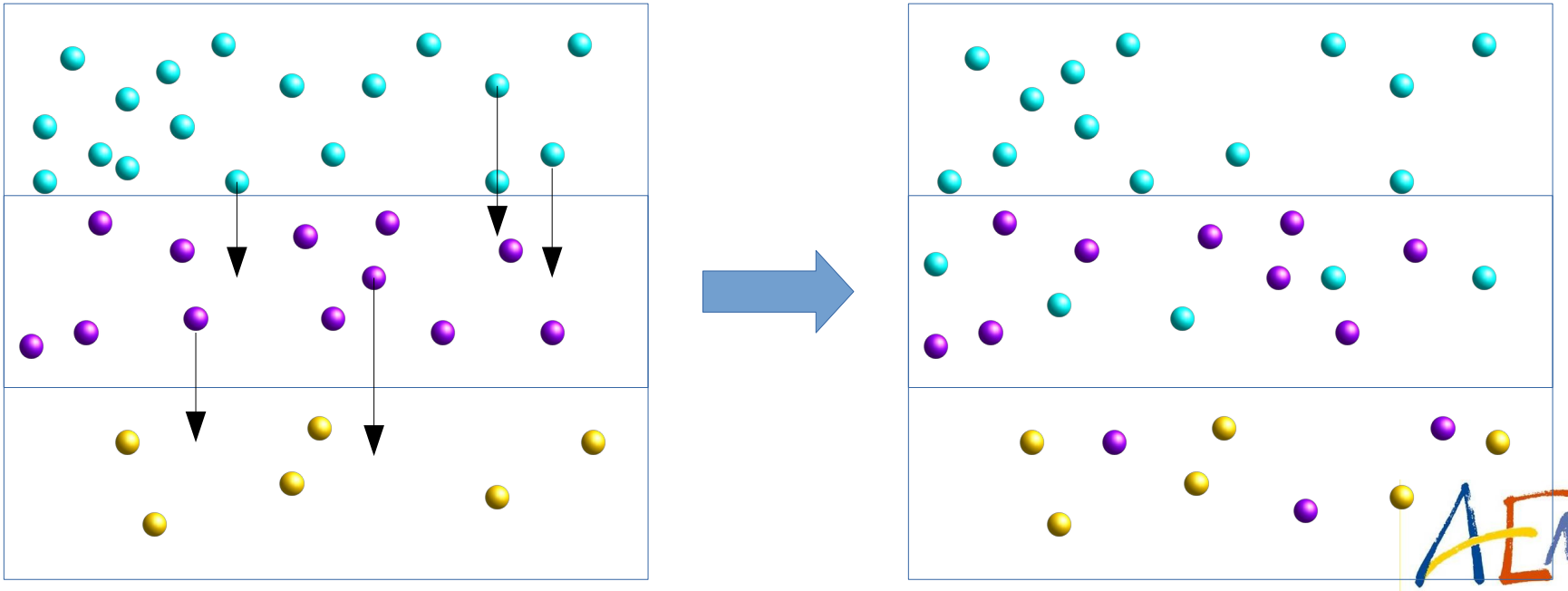
Microphysics

Cloud droplet sedimentation

The cloud droplet sedimentation depends on the terminal velocity of the droplet (function of the droplet radius) and the droplet size distribution assumed (generalized gamma law)

$$\mathrm{RSEDR} = \frac{1}{\rho_a}\frac{\partial}{\partial z}\int_0^\infty \frac{\pi}{6}\rho_w D^3 V(D) N(D)\,\mathrm{d}D$$

$$= \frac{\partial}{\partial z}\left\{ c\left(\frac{\rho_{00}}{\rho_a}\right)^{0.4} r_r \frac{\Gamma(\nu_r + \{d+3\}/\alpha_r)}{\lambda_r^d \Gamma(\nu_r + 3/\alpha_r)} \right\},$$



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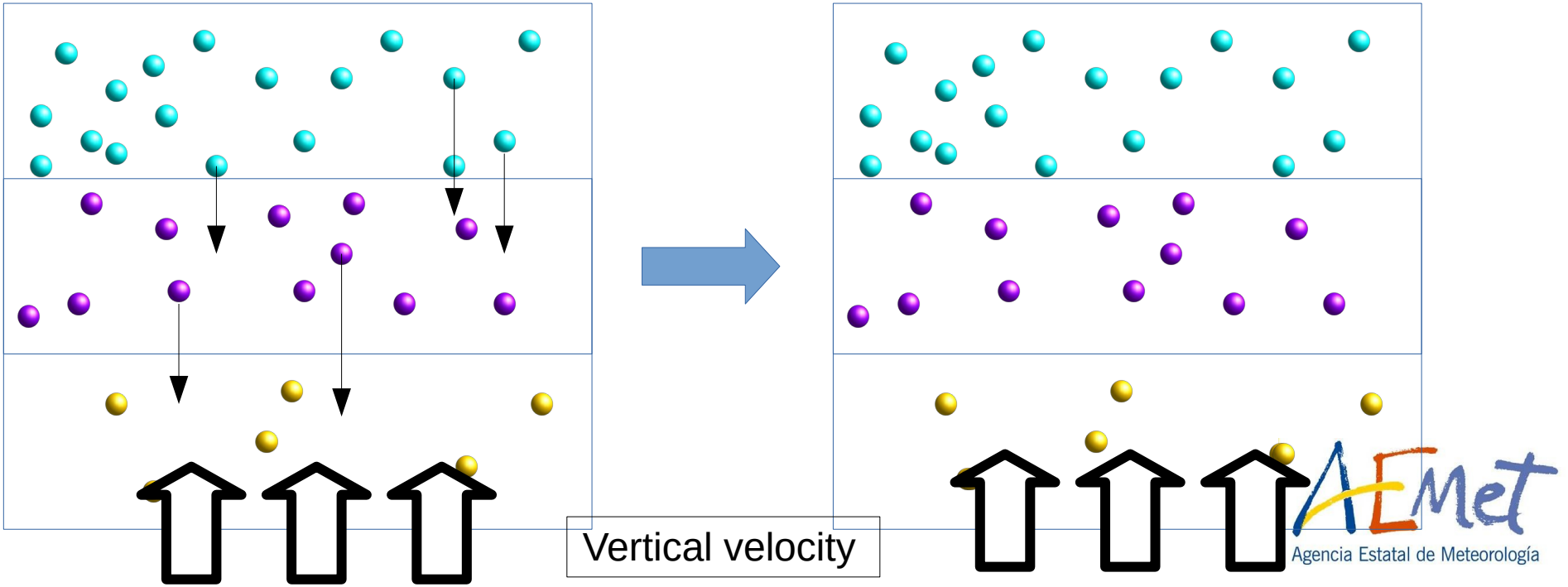
Microphysics

Cloud droplet sedimentation modification

It was found that the cloud droplet sedimentation with cloud droplet number concentration from NRT aerosols was reducing the precipitation for high precipitation ranges.

A modification in the parametrization considering the vertical velocity was introduced to avoid sedimentation in cases of high vertical velocities.



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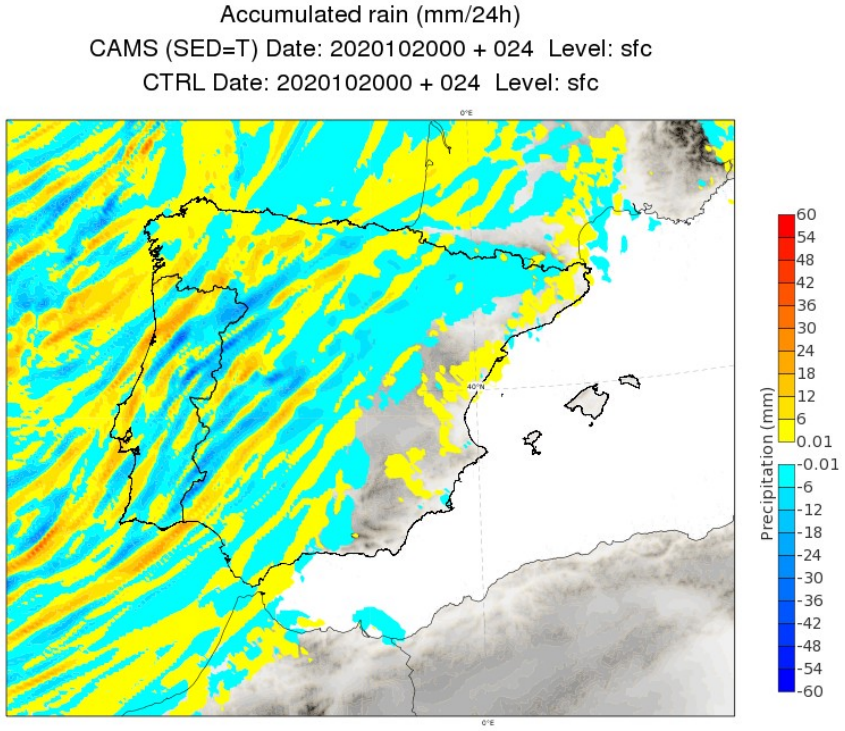
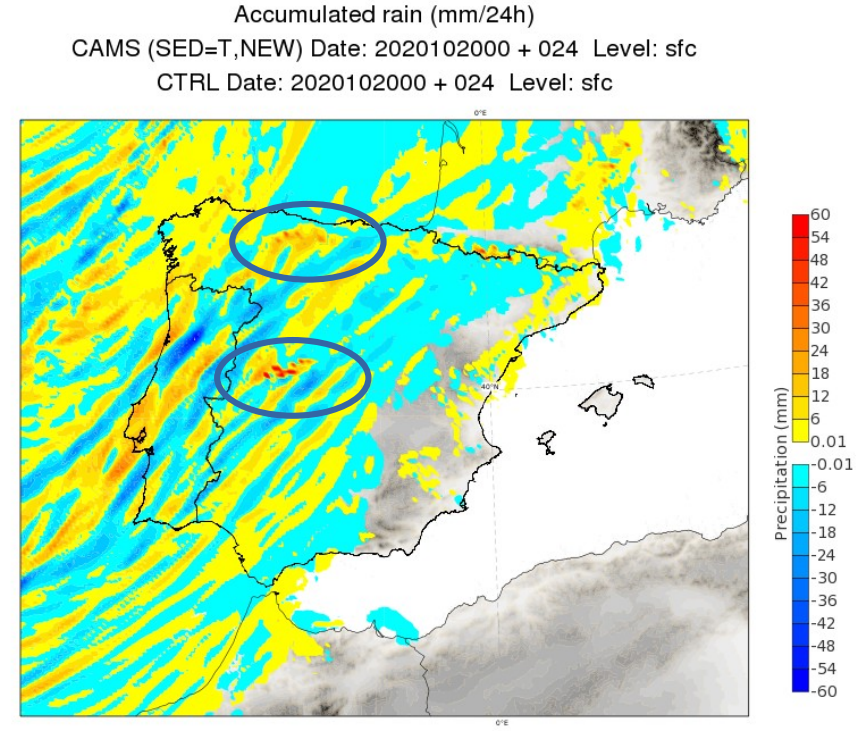
Microphysics

Cloud droplet sedimentation

When the vertical velocity is considered in the sedimentation of cloud droplets, an increment of the precipitation over the mountain ranges is found (right images)

This modification hasn't been considered in the CTRL case





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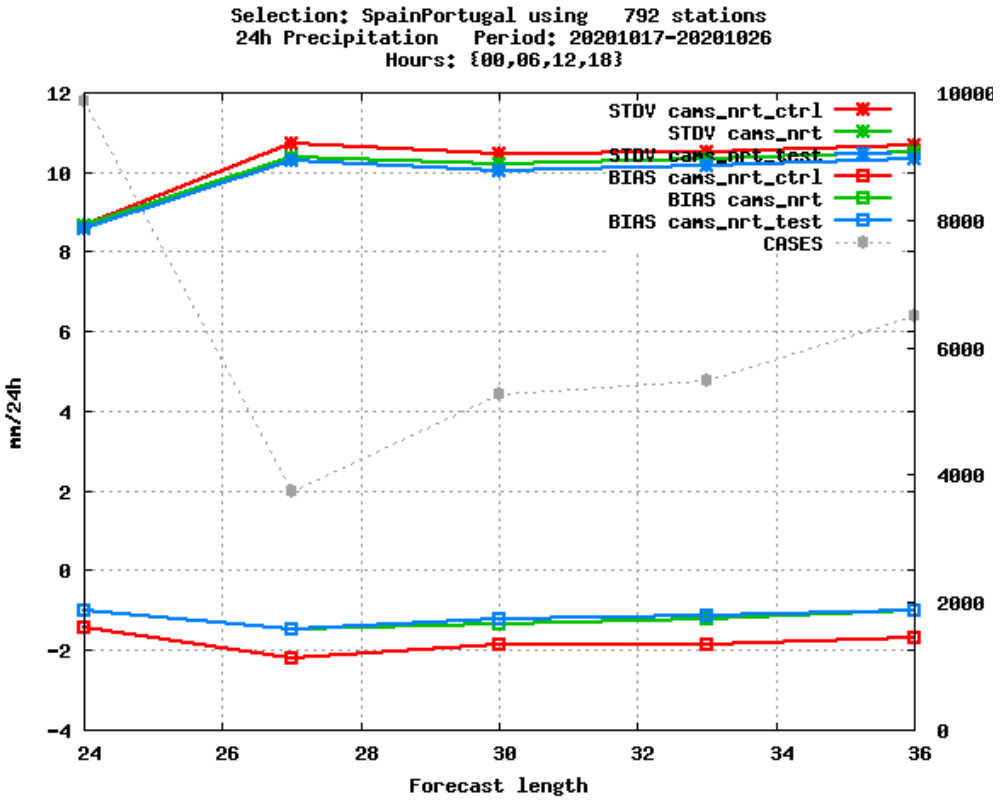
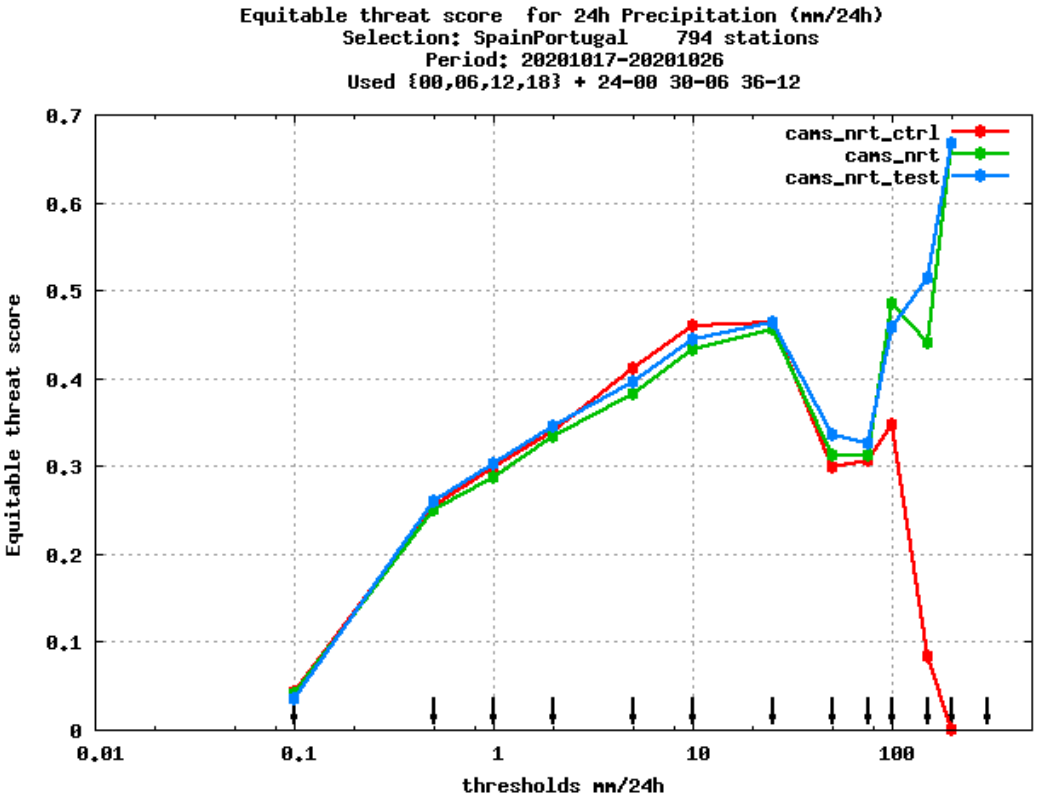
10 days verification (oct. 2020)

BIAS & STDV vs. Forecast length

24H Precipitation

ETS vs. thresholds





10 days verification:
17/10/2020-26/10/2020
24H precipitation.
Experiments: **CTRL** (default values of CCN 300cm-3 over land and 100cm-3 over sea), **CAMS aerosols** and **CAMS aerosols with Microphysics modifications**

There is an improvement when the modifications in the autoconversion and sedimentation are introduced, but in the range around 10mm/24h the CTRL still behaves better.

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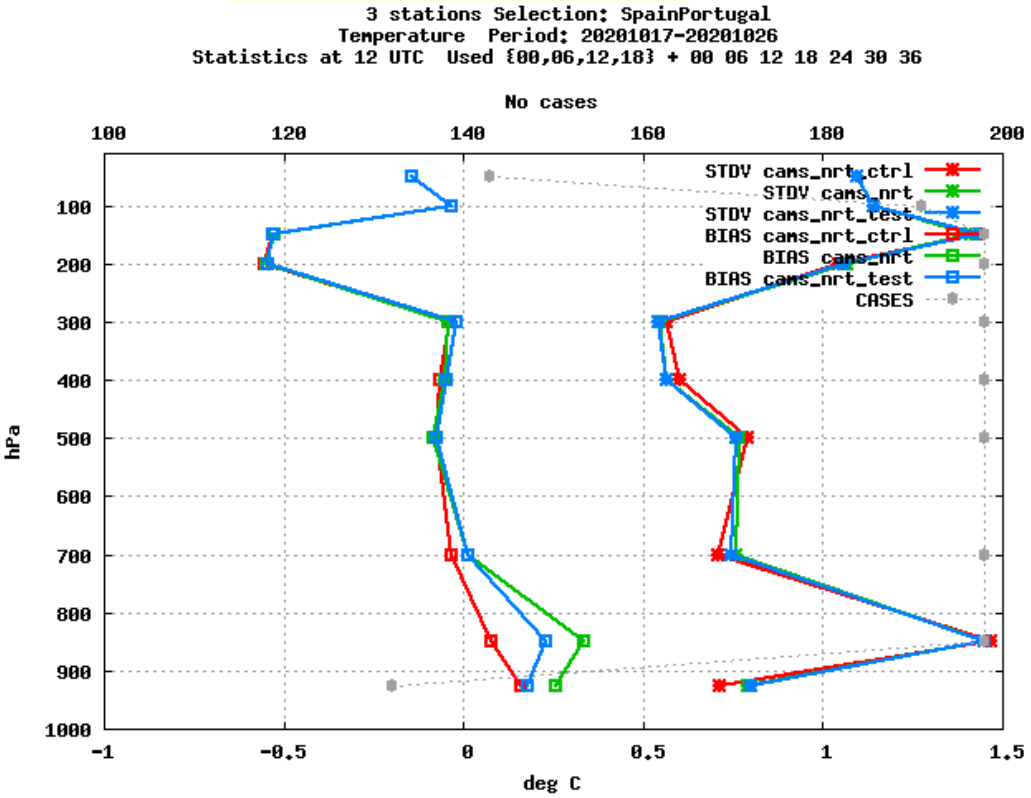
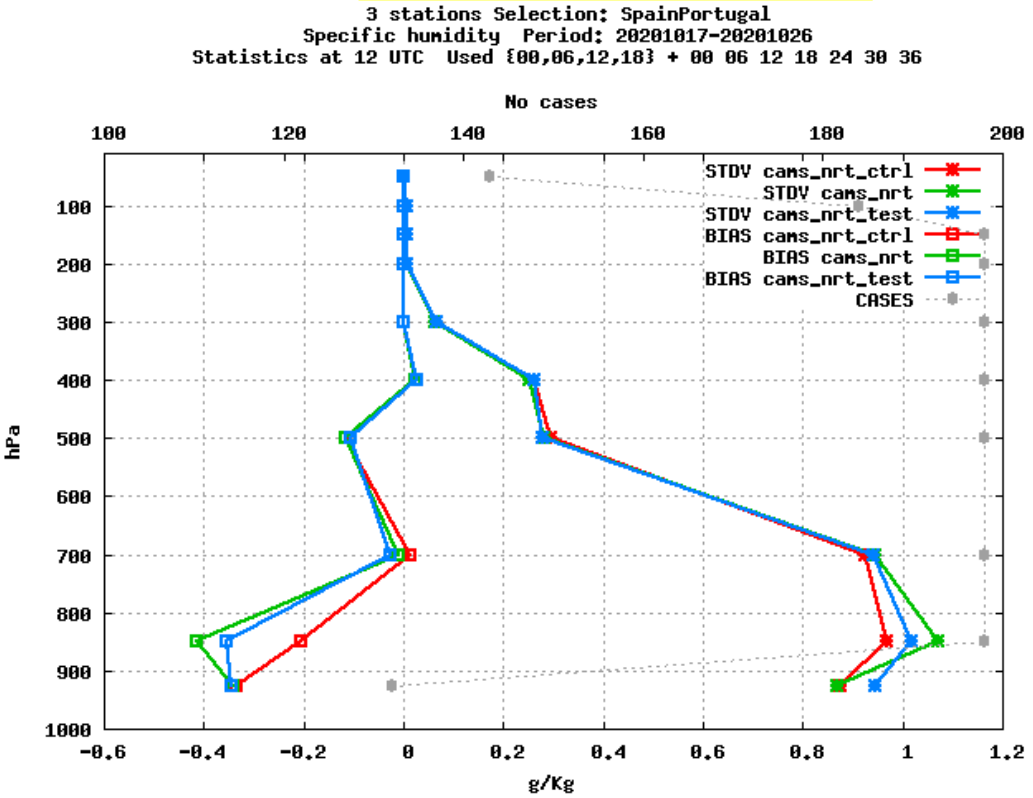
10 days verification (oct. 2020)

TEMPERATURE



SPECIFIC HUMIDITY



10 days verification:
17/10/2020-26/10/2020
24H precipitation
Red: CTRL
Green: CAMS aerosols
Blue: **CAMS aerosols with Microphysics modifications**

Still the profiles of the temperature and humidity show a warmer and dryer atmosphere, but not as much as previously.

The modifications are in the good direction.

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Conclusions

- A total number of 14 near real time aerosol species from CAMS are used in HARMONIE-AROME.
- The BC from CAMS are now interpolated in time to have them hourly (Ulf implementation)
- Use CCN of near real time aerosols in LW radiation and the calculation of the ice nuclei have been developed (but not tested).
- The SW radiation in dust intrusion cases is very well reproduced when n.r.t. aerosols are used.
- Fog is sensitive to the number of CCN.
- The inclusion of aerosol permits a better forecast in high precipitation events, but needs to be improved for low precipitation.
- The introduction of a threshold in the cloud droplet radius for the activation of the autoconversion and of the vertical velocity in the cloud droplet sedimentation improves the precipitation forecast.

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Thank you for your attention.