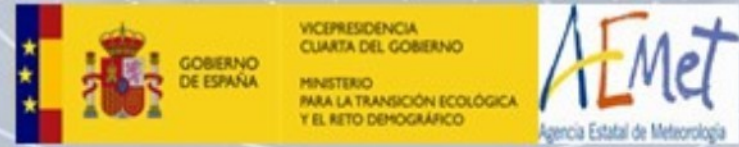# Update of the use of CAMS aerosols in HARMONIE-AROME

Daniel Martin Perez, AEMET

Collaboration: Laura Rontu, FMI; Oskar Landgren, Metno.

joint 30th ALADIN Workshop & HIRLAM ASM 2020

Outline

1. Short introduction.
2. Upgrade of CAMS (July 2019).
3. One month verification (cy. 40H11).
4. Implemetation on cycle 43.
5. Mass extinction dependence with humidity.
6. Saharan dust case in the Canary Islands.
7. What's going on?
8. Problems and code issues.
9. Computational issues.
10. Future work and Conclusion
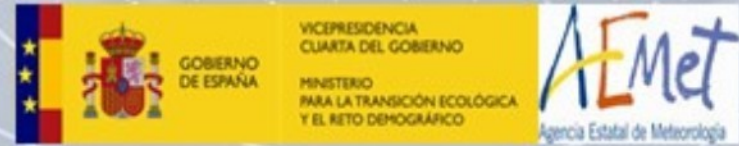
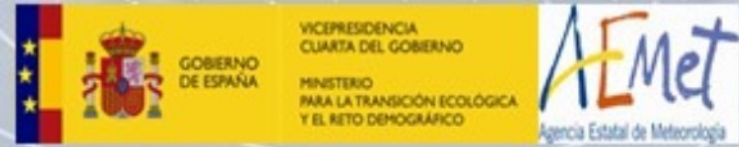HARMONIE–AROME (cycles 40h1.1 and 43h2.1tg1) has been adapted to use near real time (n.r.t.) aerosol from CAMS.

This supposes the use of 11 3D mixing ratio aerosol fields in the first guess and the boundary conditions.

The microphysic scheme and the radiation scheme are the parametrizations involved

It has supposed an increase complexity of the code: reading new fields from another source (CAMS), integrating them in the forecast, new parametrizations required,...

It's been shown the influence in dust intrusion cases. (ASM 2019)

MICROPHYSICAL SCHEME

Standard configuration (HARM):
CLOUD CONDENSATION NUCLEI concentration is presumed:
      * XCONC_SEA=100/cm3; XCONC_LAND=300/cm3; XCONC_URBAN=500/cm3

Use of CAMS aerosols (HARM+CAMSnrt):
CCN concentrations are obtained from CAMS n.r.t. aerosol mixing rations

   * 6 3D fields of mixing ratio of aerosols: *3 sea salt types, hydrophilic BC, OM 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.

Incidence on parametrizations:
- Autoconversion (cloud droplets → rain droplets)
- Cloud droplet sedimentation.
- Collision of cloud liquid.
- NOT ON THE CONDENSATION/EVAPORATION
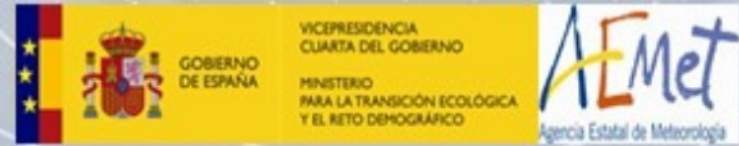
RADIATION SCHEME

Standard configuration (HARM, Using climatological values):
In HARMONIE–AROME the direct radiative effects of aerosols consider:
        * AOD550 (4 tegen species: SEA, LAND, SOOT, DESERT) surface fields initialized from climate FA file
        * Vertical profiles are presumed.

Using CAMS n.r.t. mass mixing rations (HARM+CAMSnrt):
        * The vertical distributions are calculated from the aerosol mixing ratio fields and a constant mass extincion coefficient at 550 nm 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)
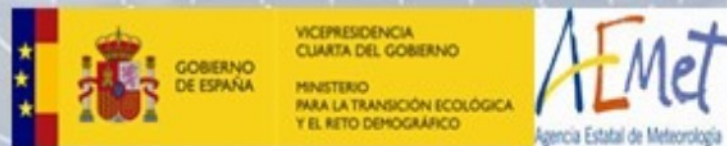   SEA   = Sea salt(1) + Sea salt(2) + Sea salt(3)
            DESERT = Desert dust(4) + Desert Dust(5) + Desert dust(6)
            SOOT   = Hydrophobic Black Carbon(9) + Hydrophilic Black Carbon(10)

Impact on the SW radiation

On 9th of July 2019 the CAMS system was upgraded

Changes to take into account:

Increased of the number of levels from 60 to 137

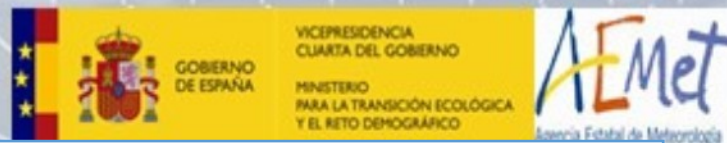New aerosol fields: nitrate and amonium

Info about the upgrade: https://atmosphere.copernicus.eu/node/472

Level correspondence: L60 – L137

N(L60)	p_L60[hPa]	N(L137)	p_L137[hPa]
...	...	...	...
57	998.3854	132	996.9452
58	1004.644	134	1003.7906
59	1009.056	136	1009.5363
60	1012.049	137	1012.0494

CAMS general

+ Horizontal resolution of the CAMS Global data is ~40 km (T511L60)

+ Output data available at a 3-hour intervals.

+ Two 5-day forecasts per day, starting from 00 UTC and 12 UTC, respectively.

	until 09/07/2019	from 09/07/2019 (UPGRADE)
+ Number of levels in the vertical:	60	137
+ Number of aerosol species:	11	14

clear increase of mineral dust

Name	Short Name	Param eter 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

New aerosol species

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
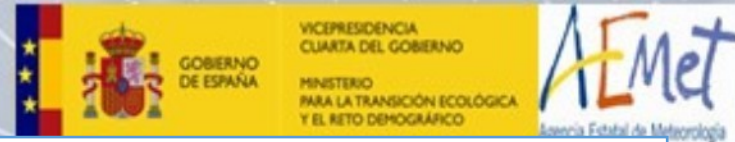
VICEPRESIDENCIA CUARTA DEL GOBIERNO
GOBIERNO DE ESPAÑA
MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA Y EL RETO DEMOGRÁFICO

AEMet
Agencia Estatal de Meteorología

CAMS general

• Horizontal resolution of the CAMS Global data is ˜40 km (T511L60)

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	until 09/07/2019	from 09/07/2019 (UPGRADE)
• Number of levels in the vertical:	60	137
• Number of aerosol species:	11	14

clear increase of mineral dust

Name	Short Name	Parameter ID
Sea Salt Aerosol (0.03 - 0.5 um) Mixing Ratio	aermr01	210001
Hydrophilic Black Carbon Aerosol Mixing Ratio	aermr10	210010
Sulphate Aerosol Mixing Ratio	aermr11	210011

HARM+CAMSnrt for cy. 40h1.1 and cy. 43h2.1tg1 were updated to consider 137 vertical levels from 09/07/2019

The three new aerosol species hasn't been included yet.

One moth verification (September 2019) of cy. 40h11 of HARM+CAMSnrt.

- Microphysics and radiation both included.
- Sedimentation parametrization considered as well.
- <u>No cycling for the aerosols</u>, the first guess fields of the aerosol MR is taken from CAMS.
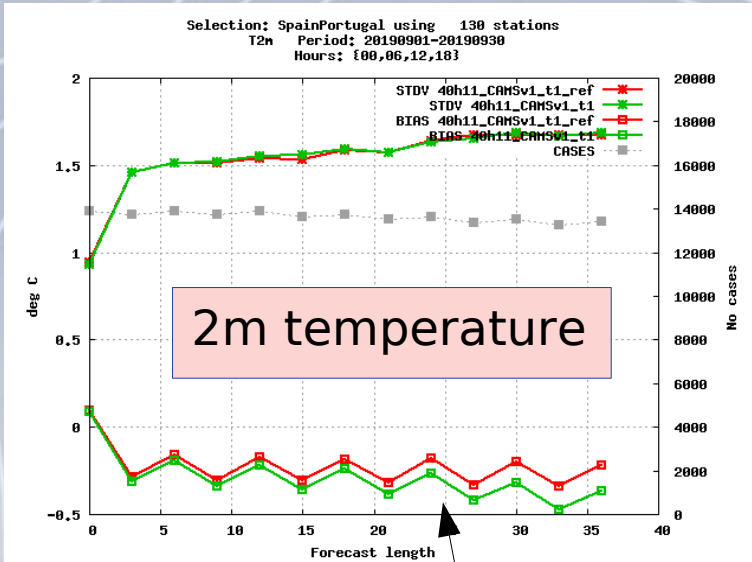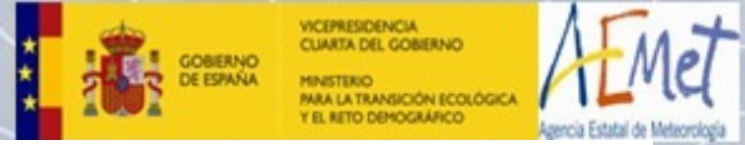
Summarize:

    Good results of the ets of the precipitation.

    Degradation of the temperature with increaing forecast lenght

Degradation of temperature might be due to not to take into account the humidity in the mass extinction ???

3. One month verification (cy. 40h11)
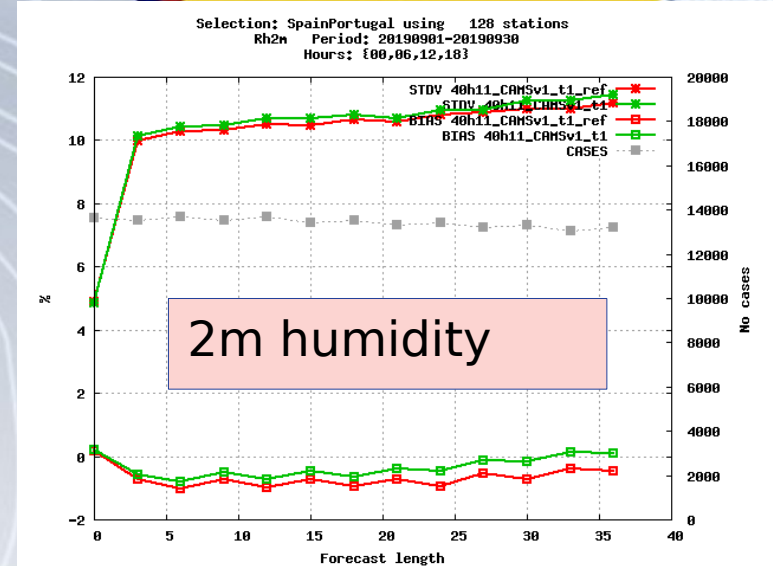
Cycle version 40h11
1 mont verificaion (September 2019)

RED: Control
GREEN: n.r.t. CAMS

TEMPERATURE: STDV: Similar values
                BIAS: Degradation with increasing forecast lenght.

HUMIDITY: STDV: Similar values.
                BIAS: Improvement with increaing forecast lenght.

Possible reasons:
* not considerig the mass extinction as a function of the humidity
* the parametrization of sedimentation not well adjusted

Equitable threat score for 6h Precipitation (mm/6h)
Selection: SpainPortugal   101 stations
Period: 20190901-20190930
Used [00,06,12,18] + 06-00 12-06 18-12 24-18 30-24 36-30

Equitable threat score for 24h Precipitation (mm/24h)
Selection: SpainPortugal   126 stations
Period: 20190901-20190930
Used [00,06,12,18] + 24-00 30-06 36-12
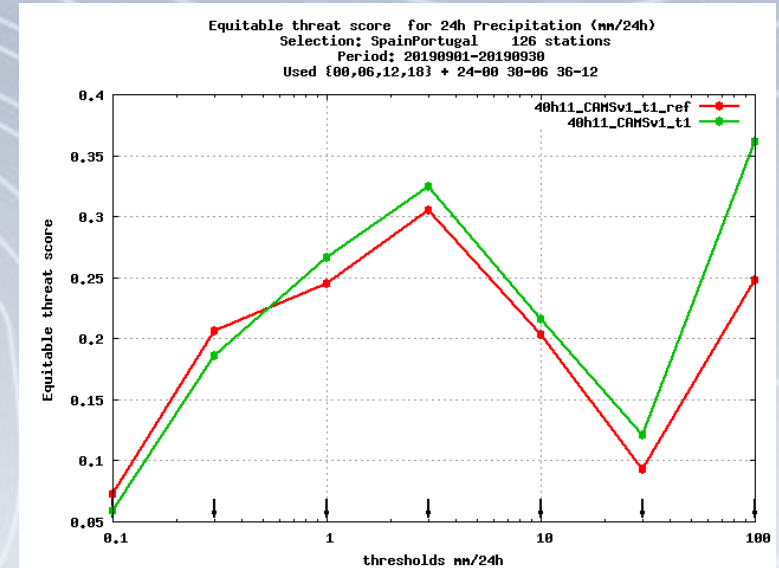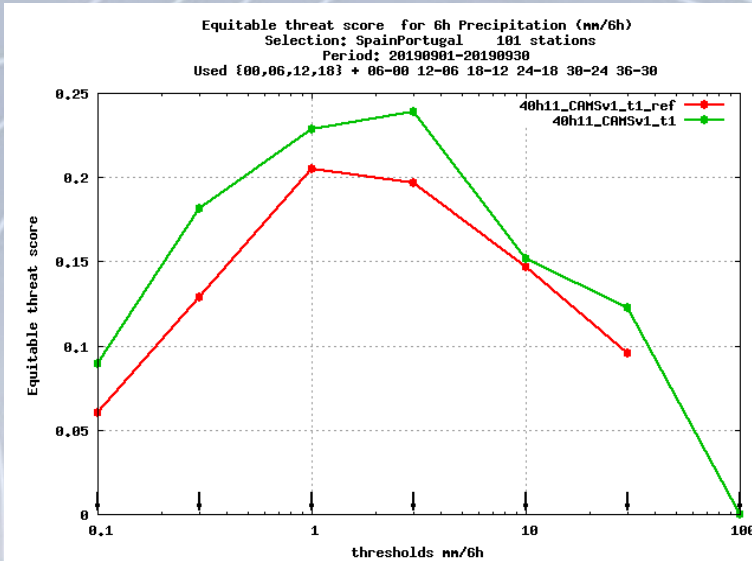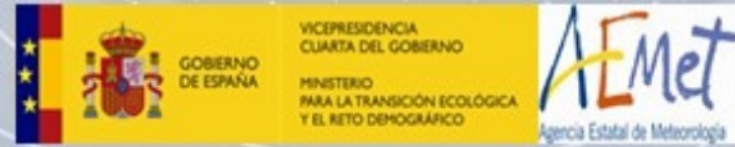
Precipitation: 1 month verification
September 2019

RED: Control
GREEN: n.r.t. CAMS

6h Precipitaion: ETS: Improvement
24h Precipitaiton: ETS: Improvement.

Not a rainy month.

It's been adapted to cycle 43h2.1tg1.

The code is in the git repository (user: dmartin)

Case study: Impact of aerosol on precipitation pattern.

    2019/09/21:
    DTG=2019092100 Cold start
    24h accumulated precipitation
    Experiments:
    * 40h1.1
    * 40h1.1 HARM+CAMSnrt
    * 43h2.1tg1
    * 43h2.1tg1 HARM+CAMSnrt

4. Implemetation on cycle 43
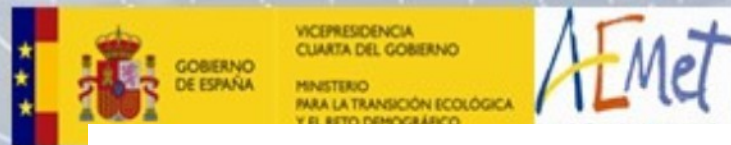
24h acc. Precipitation
2019/09/21 H00+24

Accumulated rain
40h11_CAMSv1_t1_ref Date 20190921 H 00+24 Level: sfc
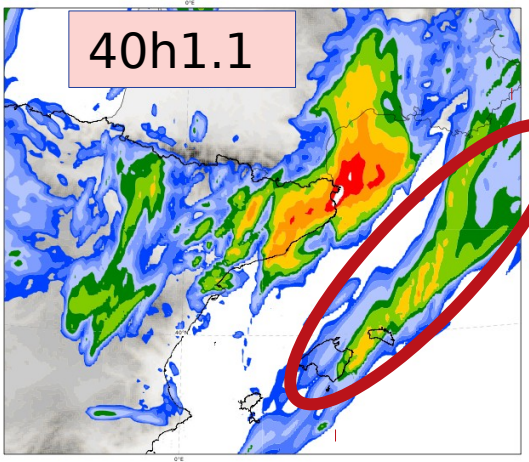
40h1.1

Accumulated rain
40h11_CAMSv1_t1 Date 20190921 H 00+24 Level: sfc

40h1.1 + nrt CAMS
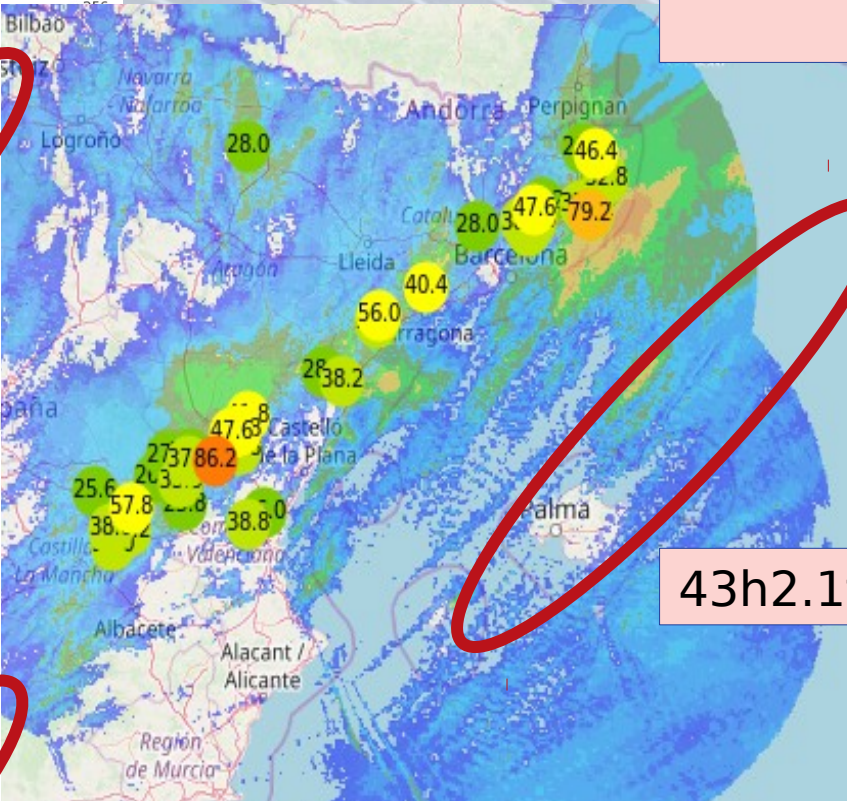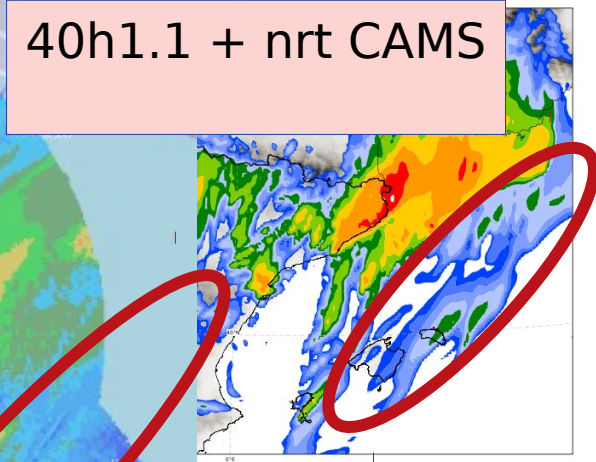
Accumulated rain
43tg1_CAMSv1_t1_ref Date 20190921 H 00+24 Level: sfc

43h2.1tg1
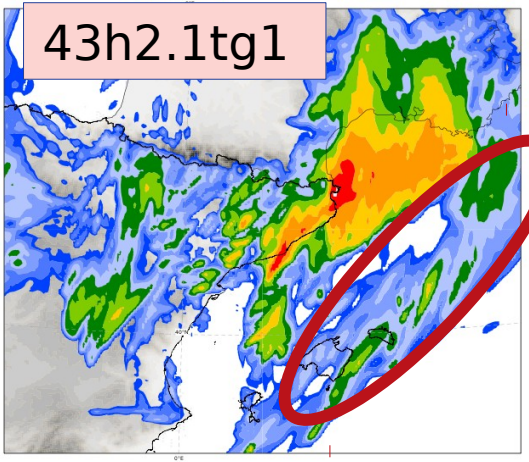
Accumulated rain
MS_1g Date 20190921 H 00+24 Level: sfc

43h2.1tg1 + nrt CAMS
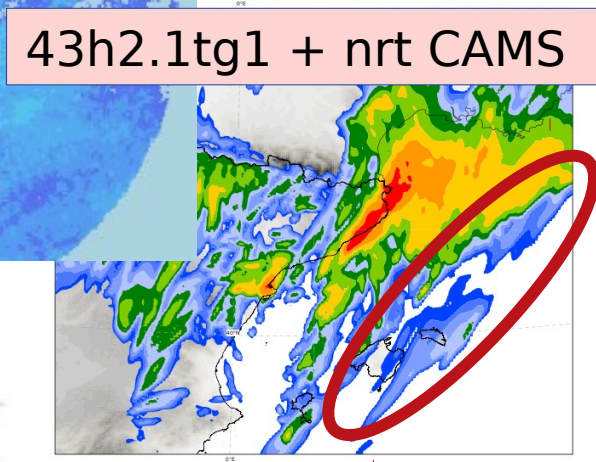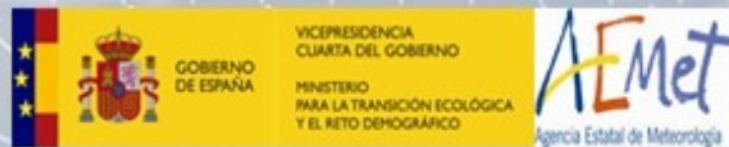
The mass extinction of hidrophilic aerosol species depends on the humidity.

Humidity dependence of mass extinction was first ignore.

The code was updated to take into account the humidity dependence (only for cycle 43h2.1tg1 for the time being)

In general, higher values of the global radiation with the humidity correction (less extinction) and closer to observation.

## 5. Mass extinction dependence with humidity.

Global radiation at Caceres station compared with observation (black dashed line) values. The red curve is the control (climatology), the blue is using CAMS n.r.t with constant mass extinction and the green with the humidity correction

GHI. Caceres: 39.47, -6.34
Date: 2019090800
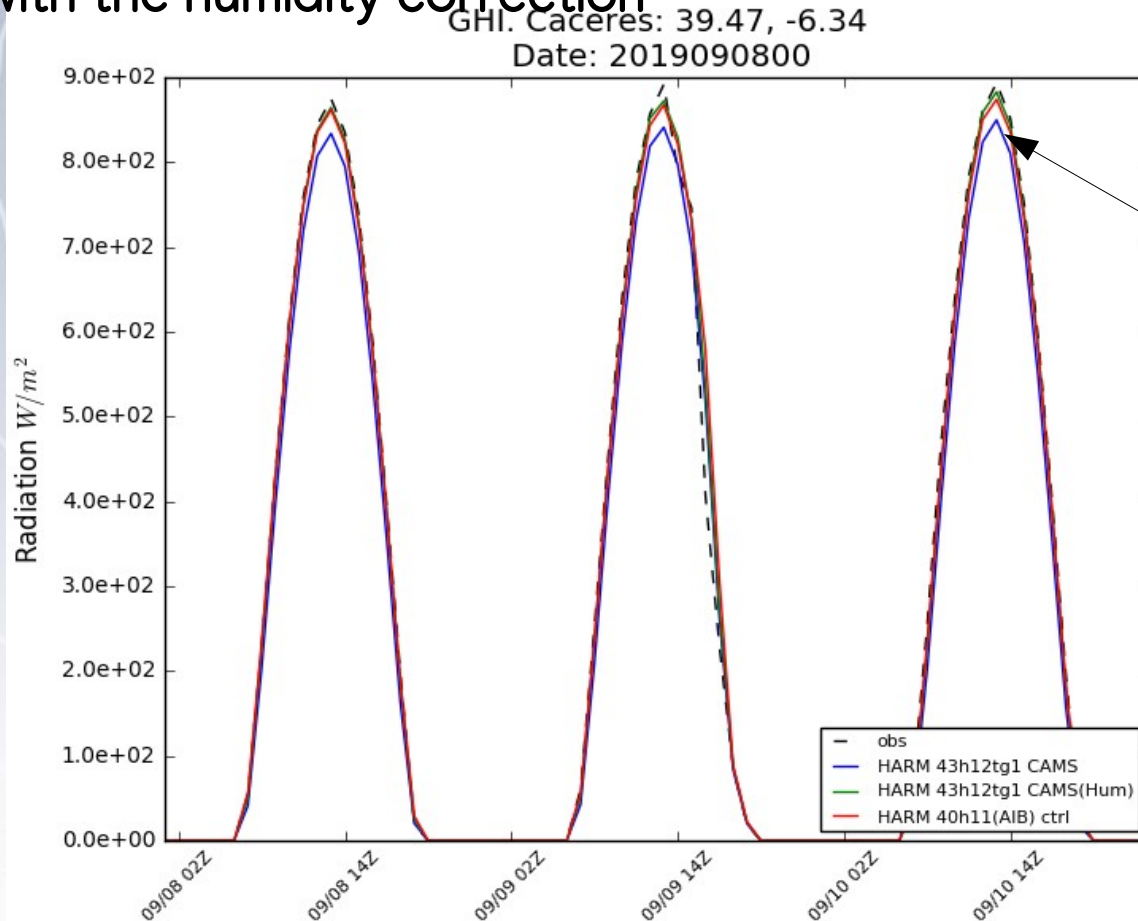
Blue line, constant mass extinction, lower values of global radiation, (=stronger extinction).

Difference of 36 W/m² (4%)

Direct normal irradiance
AIB Date 20190908 H 00+12 Level: sfc
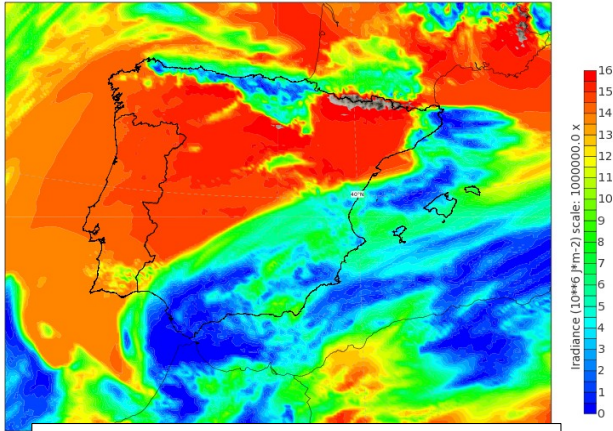
Ref. op. 40h1.1
(Tegen climatology)

Higher impact on the direct normal irradiance (dni)

* Without humidity dependence (lower left), the dni is too low compared with the reference (upper left).
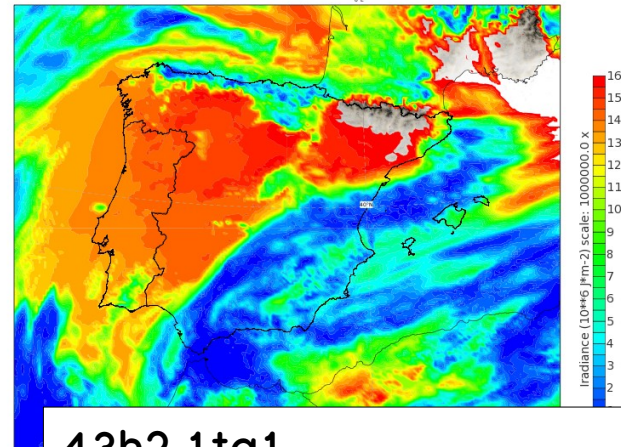
* With the humidity correction (lower right), values are closer to reference.

Direct normal irradiance
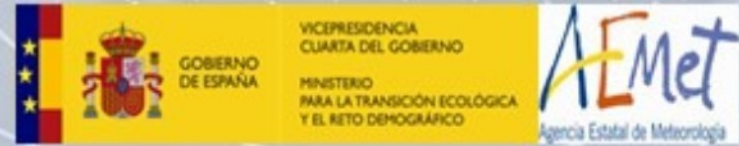43h12tg1_CAMS_1g Date 20190908 H 00+12 Level: sfc
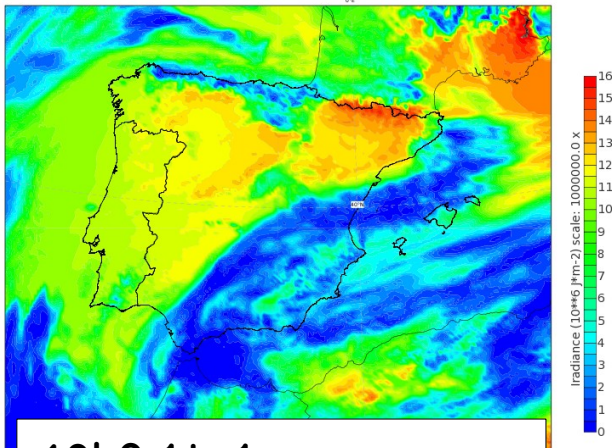
43h2.1tg1
CAMS aerosols

Direct normal irradiance
43h12tg1_CAMS_1g_new Date 20190908 H 00+12 Level: sfc

43h2.1tg1
CAMS aerosols (humidity corr.)

6. Saharan dust case in the Canary islands.

Strong Saharan dust intrusion in the Canary islands in february 2020. On the 23/02/2020 the dust intrusion reached its peak.

A three days run experiment was executed starting 2020022100 until 2020022400 using cycle 43h2.1tg1 with 3hours cycling. (taking the aerosol MR fields in the BC every 3 hours)

The comparison of the global radiation forecast with observations was bad.

The aersols MR fields were not cycling with cycle 40h1.1, but they are cycling with cycle 43h2.1 !! and as there is no aerosol generation in the code, the dust amount went down as part of the area of dust production is inside the domain

A cold start for 2020022300 with nrtCAMS aerosol in the first guess shows a much better agreement.
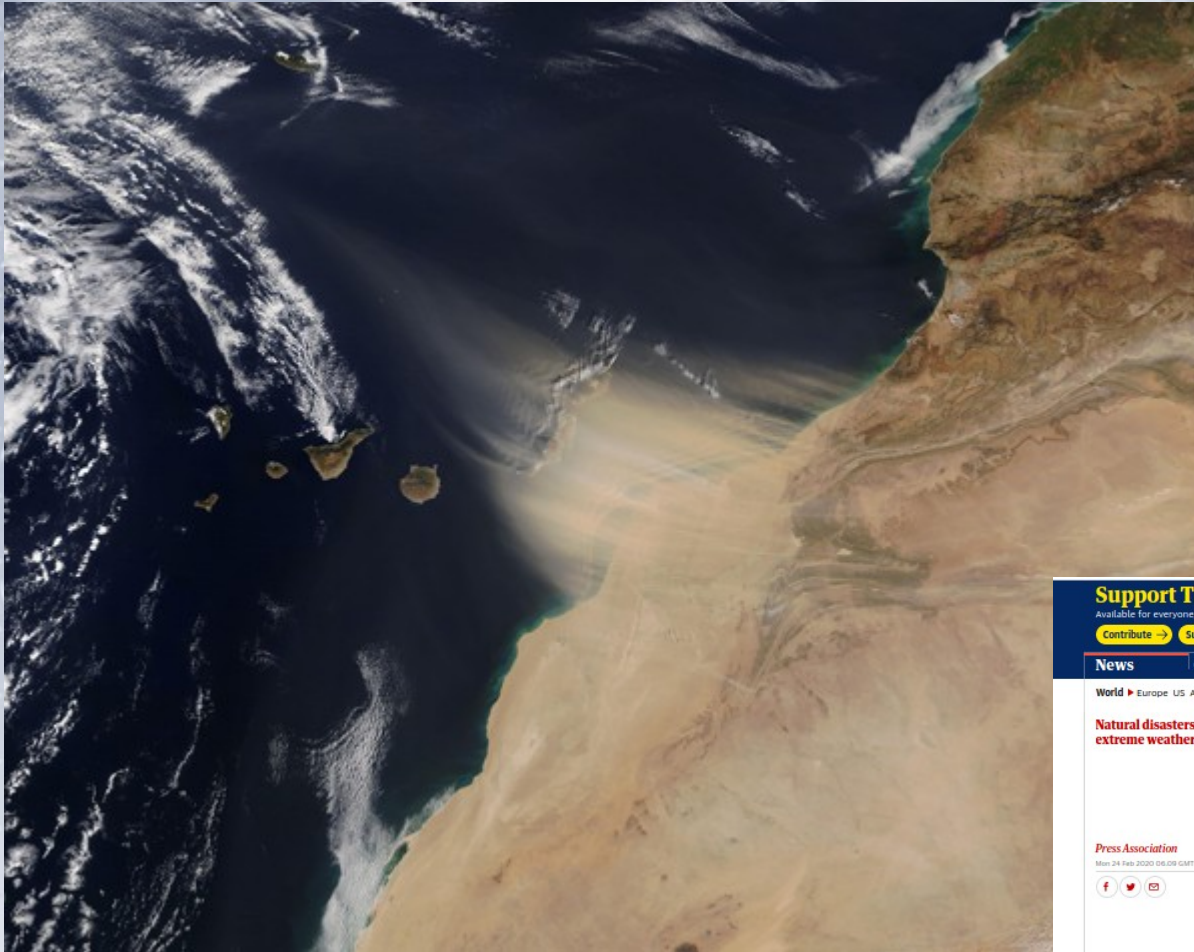
Airports were closed.
Very low visibility.

Canary islands 23/02/2020
MODIS on NASA's Terra satellite

6. Saharan dust case in the Canary islands.

Global radiation (W/m2) Site: Maspalomas 20200221-23

GHI. Maspalomas: 27.76, -15.57
Date: 2020022100

obs
HARM 43h2tg1+CAMS
HARM 43h2tg1+CAMS (HUM)
HARM 40h11(AIC) ctrl
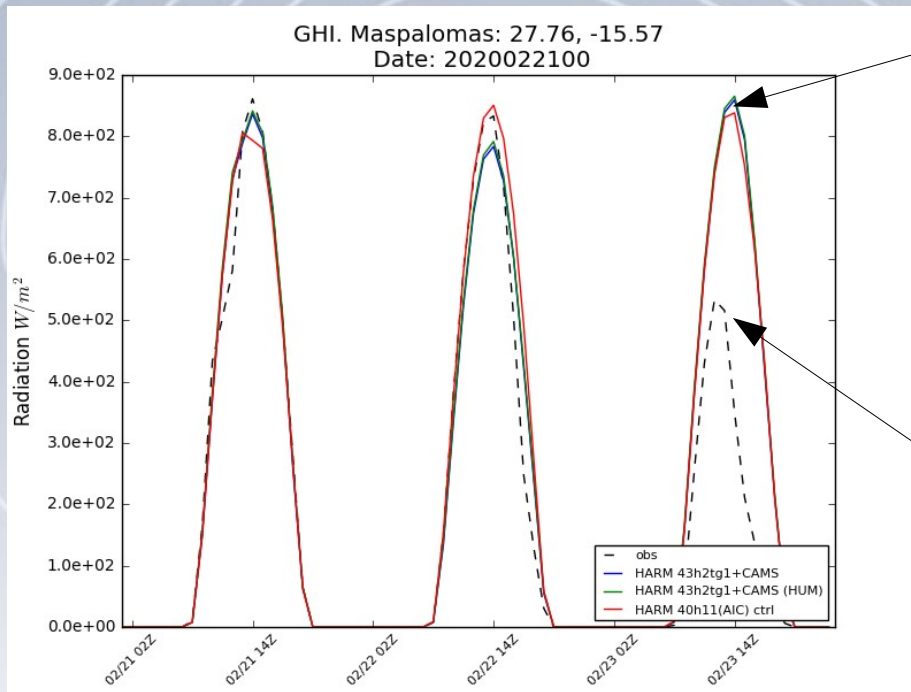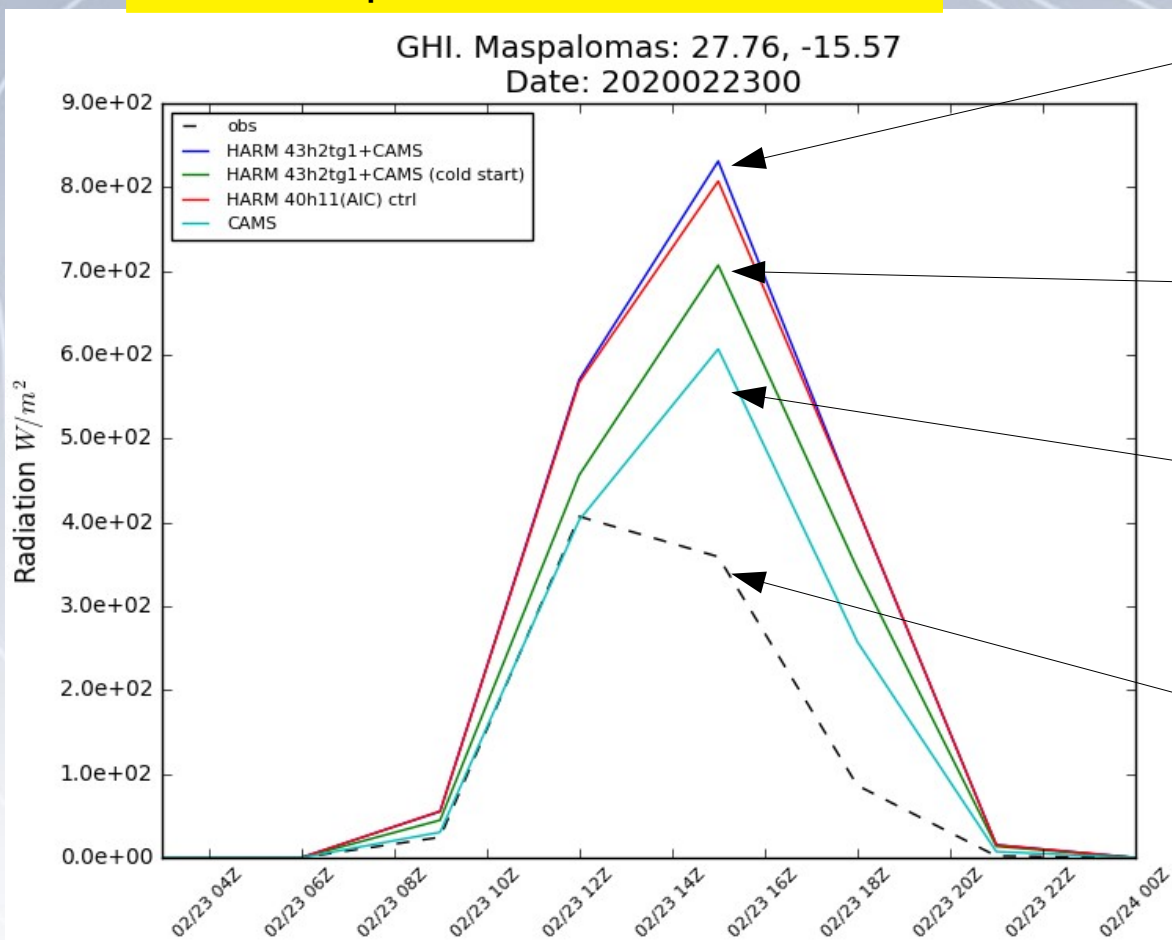
The three experiments (43h2.1tg1): control, HARM+CAMSnrt and HARM+CAMSnrt (humidity corr.) gives similar values after 3 days forecast

Much lower values observed in the peak day of the dust intrusion.

Unfortunally high clouds were also observed during the day, so the disminution might be the contribution of both!!

6. Saharan dust case in the Canary islands.

Global radiation (grad) (W/m2)
Site: Maspalomas 20200223

GHI. Maspalomas: 27.76, -15.57
Date: 2020022300

Legend:
- obs
- HARM 43h2tg1+CAMS
- HARM 43h2tg1+CAMS (cold start)
- HARM 40h11(AIC) ctrl
- CAMS

HARM+CAMSnrt after three days forecast with 3h cycling

HARM+CAMSnrt cold start
DTG=202002300

CAMS
cfVarNameECMF = ssrd;
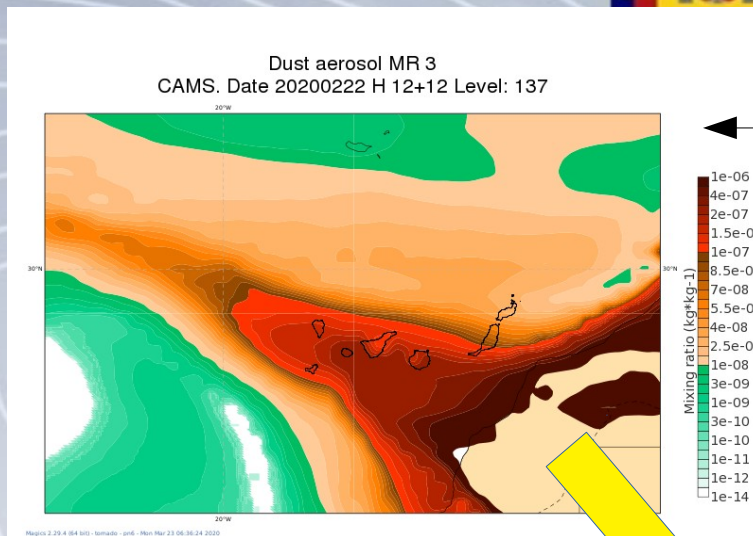nameECMF = Surface solar radiation downwards;

Observation

6. Saharan dust case in the Canary islands.

Dust MR for lower level at 2020/02/23 00Z
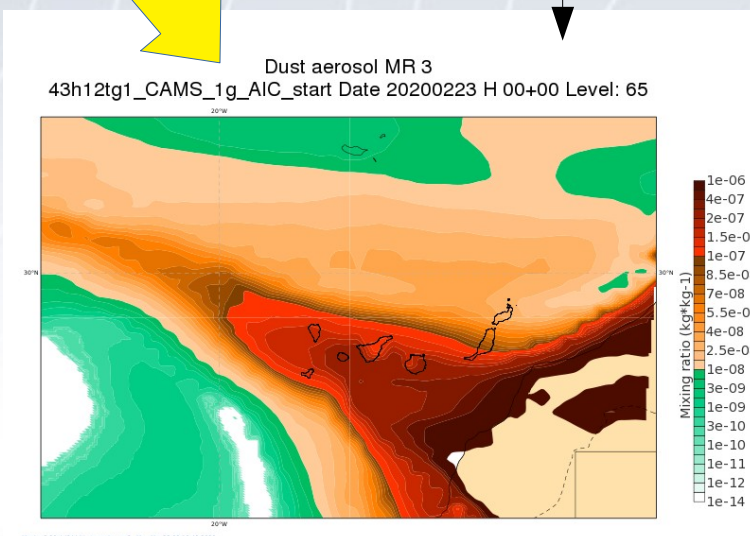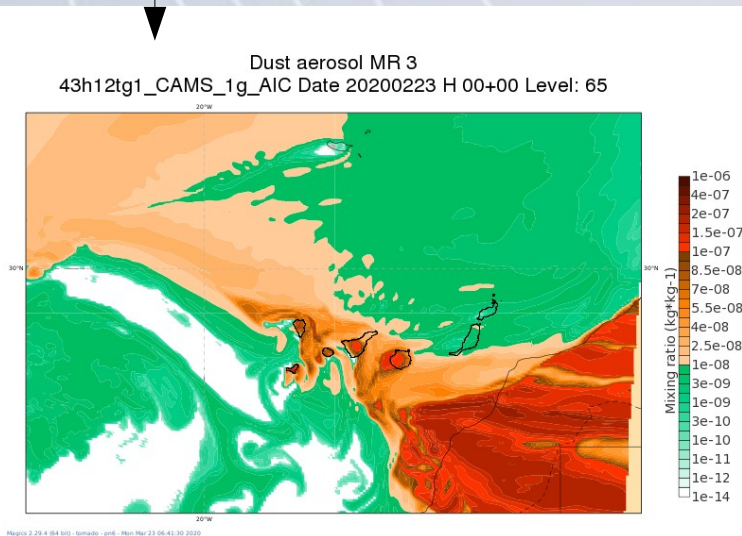
HARM+CAMSnrt cy 43
Two days warm up with cycling.

2020022300+00
(first guess)

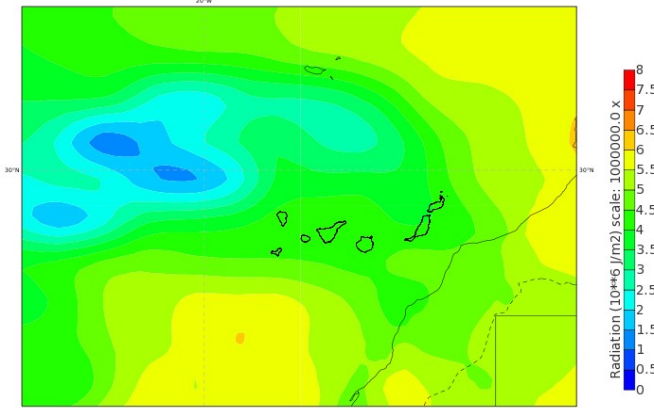CAMS 2020022212+12

HARM+CAMSnrt cy. 43
Cold start

DTG=2020022300
First guess

Dust aerosol MR 3
CAMS. Date 20200222 H 12+12 Level: 137

Dust aerosol MR 3
43h12tg1_CAMS_1g_AIC Date 20200223 H 00+00 Level: 65

Dust aerosol MR 3
43h12tg1_CAMS_1g_AIC_start Date 20200223 H 00+00 Level: 65
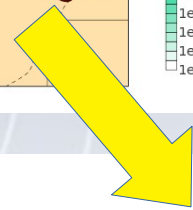
6. Saharan dust case in the Canary islands.

3hours accumulated solar radiation (SW) 2020/02/23 12Z

CAMS 2020023h00+12

HARM+CAMSnrt cy 43
Two days warm up with cycling.

2020022300+12

Solar radiation(Global)
Accum. last 3 hours. Date 20200223 H 00+12 Level: sfc
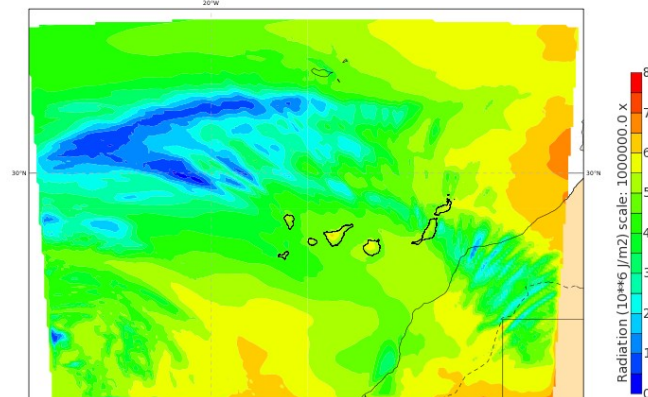
HARM+CAMSnrt cy. 43
Cold start

DTG=2020022300+12

Acc. Global radiation flux
Accum. last 3 hours. Date 20200223 H 00+12 Level: sfc
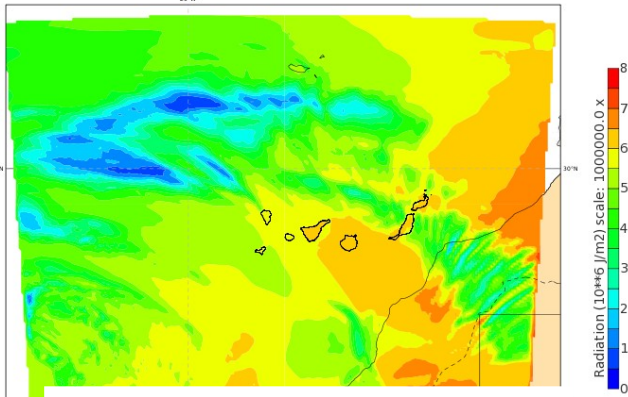
Higher SW radiation (less dust content)

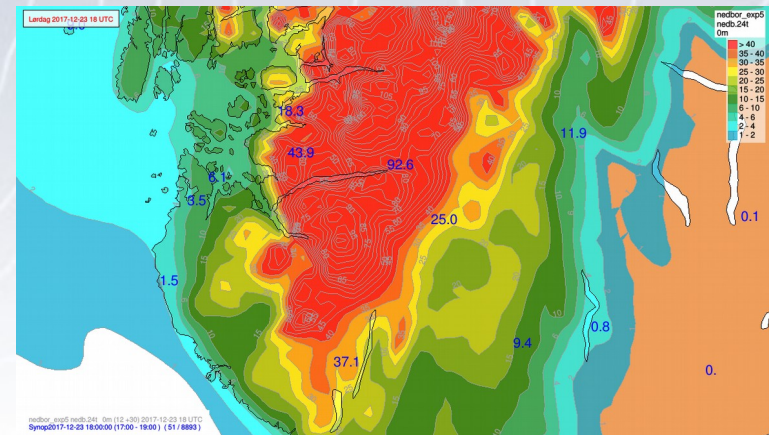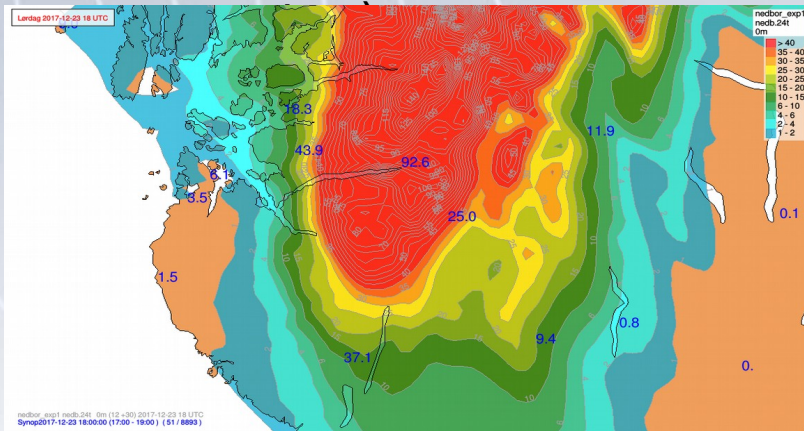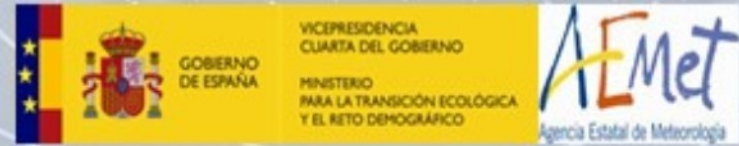Acc. Global radiation flux
Accum. last 3 hours. Date 20200223 H 00+12 Level: sfc

Studies of sensitivity of radiation parametrizations to aerosol (Rontu et al., 2020, MDPI Atmosphere) by Laura Rontu in collaboration with Emily Gleeson, Kristian Pagh Nielsen and Velle Toll (see Laura Rontu's presentation)

Test case southwestern Norway on 2017-12-23 (Oskar Landgren,

- Problems detected
  - Occasionally high values of the aerosol MR after forecast lengths of 30 h.
  - Negative values of aerosol mass mixing ratios in the outputs.
  - Only 3Dvar works not blending
  - Problems with the BC (solved by Oskar Landgren, metno)
- Code issues
  - Cy. 40h11:
    - At the local supercomputer in AEMET and at the ECMWF
    - Update after CAMS upgrade
    - ~~Still no version uploaded to the repository~~ Already in the git repository
  - Cy. 43:
    - ~~Adaptation to this cycle not yet started~~ Compiled, running and under test at the ECMWF
    - In the git repository (user: dmartin)
    - Still not in the repository version with mass extiction humidity dependence.

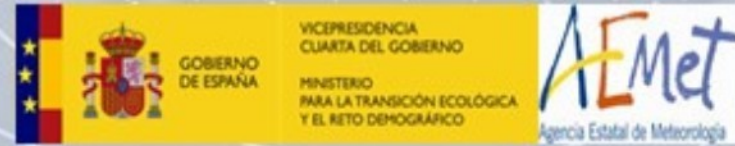## Computational issues

- How much time does the forecast take compared with the control?

  - ~~Still not check~~ 24 hour forecast (40h1.1)

|	CAMS	REF
Dispatched	Mon Nov 4 09:09:57 2019	Mon Nov 4 09:04:42 2019
Completed	Mon Nov 4 11:05:11 2019	Mon Nov 4 10:46:12 2019
Runtime	6914 seconds (+14%)	6065 seconds

- Higher memory requirements for gl_grib_api

Future work

- Parametrization of the dry deposition, specially needed for dust (in progress). Done, under test
- Introduction of the mass extinction dependence with the humidity. Done (under test)
- Further, 3D wavelength–dependent aerosol optical properties of aerosol mixture for radiation schemes (see Rontu et al., 2020)
- Verification of the new configuration for microphysics and radiation. (in progress) only 1 month,
- Parametrization of the condensation to consider CCN condentration. (in progress)
- Cycling of the version. (Parametrization of aerosol production needed)
- Parametrization of the sea salt formation.
- Contact CAMS responsible to get hourly CAMS files for a test.
- Introduce some modifications in the microphysical parametrization.
- New test cases of non observed fogs could be interesting
- Introduce new aerosol species (nitrate and amonium) from CAMS after upgrade
- New post processed variables as PM or AOD (fullpos or gl_grib_api?)
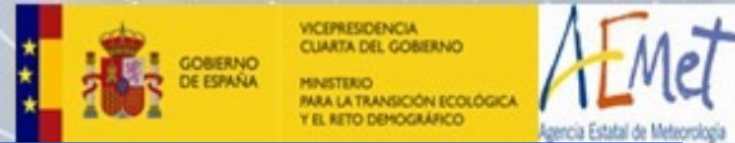
Conclusions:

The code to use nrt CAMS aerosols in HARMONIE–AROME is now available for cycle 40h1.1 and 43h2.1tg1 in the hirlam git repository (user:dmartin)

The cycle 40h1.1 gave good results in a one month verification for the precipitation, but not as good for 2m temperature. It is expected some improvement when the mass extinction dependence of the humidity is introduced.

The scripts have been updated after the upgrade of CAMS to use the grib files of 137 levels from July 2019 instead of the ones of 60 levels as before.

The mass extinction dependence with the humidity has been introduced (only in the cy. 43h2.1tg1) showing closer agreement to observations.

Unexpectlly in cycle 43h2.1tg1 the aerosol MMR fields for the first guess are taken from previous run instead of being taken from CAMS BC files, as in cycle 40h1.1. This must be changed as there is no aerosol generation in the code.

For cycle 40h11 HARM+CAMSnrt increase of run time of 14% in a 24h forecast

Thanks for your
tele-attention
and
take care.