

Cloud Aerosol Radiation Developments

Daniel Martin Perez

Based on the work of many colleagues: Emily Gleeson, Laura rontu, Karl-Ivar Ivarsson, Sander Tijm,...

5th All Staff Workshop, 31 March - 4 April 2025, Zalakaros & hybrid

- **Aerosols in the Radiation Scheme**
 - Aerosol treatment and options (**USEAERO**).
 - Clear skies period 1-15 July 2023
 - Dust intrusion case 10-12 July 2023.
- **Cloud droplets**
 - Configuration options
 - Comparison Present configuration vc. CAMS
 - Radiation scheme
 - Measurement campaign

AEROSOLS in the IFS RADIATION SCHEME

- In CY46h1 the variable **USEAERO** in *config_exp.h* permits to use different aerosol sources for the IFS radiation scheme.
- Aerosol options (**USEAERO**).
 - **tegenaod**: Default configuration, uses teegen climatic AOD (Aerosol optical depth)
 - **camscms**: Aerosol climatic MMR (mass mixing ratios)
 - **camsnrt**: Near real time aerosols from CAMS.

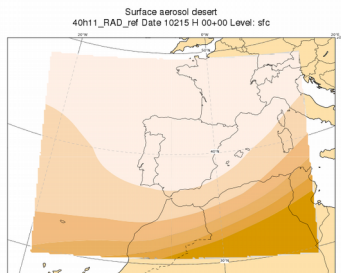
AEROSOLS in the IFS RADIATION SCHEME



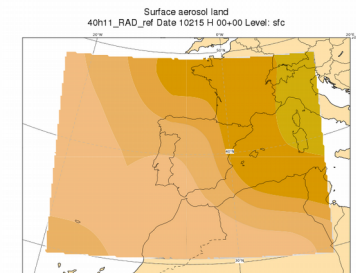
	tegenaod	camscms	camsrnt	noaero
LAEROAOD	T	F	F	F
LAEROCMS	F	T	F	F
LAERONRT	F	F	T	F
LCAMS_NRT	F	T	T	F
LAEROMIC	F	T/F	T	F
NRADLP	2	4	4	2
NAERO	0	11	14	0

- LAEROMIC: to include cloud droplets from CAMS in the microphysics and radiation.
- NRADLP=2 : default way to calculate number of liquid droplets
- NRADLP=4 : Cloud droplets obtained from aerosols.
- In the radiation scheme only 11 aerosols species are used even for camsrnt!

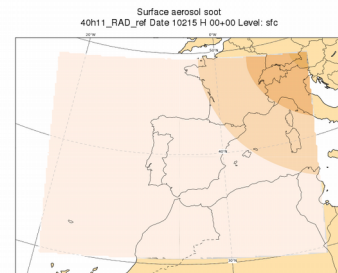
AEROSOLS in the IFS RADIATION SCHEME



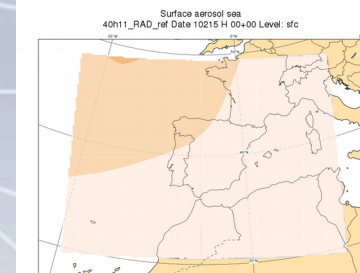
Desert



Land



Soot



Sea

IFS RADIATION SCHEME

The radiation scheme represents the aerosols in the atmosphere through the **3D AOD (Aerosol Optical Depth)** of the **4 TEGEN SPECIES FIELDS**, for every timestep (when radiation scheme is called)

In CYCLE 46h11, three options for the use of aerosols are available through the variable **USEAERO** in **config_exp.h**:

- * **tegenaod** (default)
- * **camscms** (CAMS aerosol climatology)
- * **camnrt** (CAMS near real time aerosols)

AEROSOLS in the IFS RADIATION SCHEME



tegenaod

2D **AOD (Aerosol Optical Depth)** **4 Tegen species** **MONTHLY**

Source: climatic files mMM.

Old climatology, low computational cost.

+background aerosols

- **2D → 3D:** Using a prescribed vertical distribution based on Tarré et al. (1984) climatological vertical profiles.
- **MONTHLY → Time Step:** Same values for every time step

camscms

2D **MMR (Mass Mixing Ratios)** **11 aerosol species** **MONTHLY**

Source: climatic files mMM.

New climatology, better representative, low computational cost

+background aerosols

- **2D → 3D:** Using a prescribed vertical distribution similar to Tarré et al. (1984). Other vertical distributions can be considered (Jan Masek and Piotr Sekula)
- **MMR → AOD:** The *mass extinction* for each species is known
- **Distribute 11 aerosol between 4 Tegen species:**
 - *LAND* = Sulfate + Hydrophobic Organic matter + Hydrophilic Organic Matter
 - *SEA* = Sea salt bin 1 + Sea salt bin 2 + Sea salt bin 3
 - *DESERT* = Desert dust bin 1 + Desert Dust bin 2 + Desert dust bin 3
 - *SOOT* = Hydrophobic Black Carbon + Hydrophilic Black Carbon
- **MONTHLY → Time Step:** Same values for every time step

camsrnt

3D **MMR (Mass Mixing Ratios)** **11 aerosol species** **Time step**

Source: Boundaries and first guess.

Realistic representation of aerosols, higher computational cost (15%).

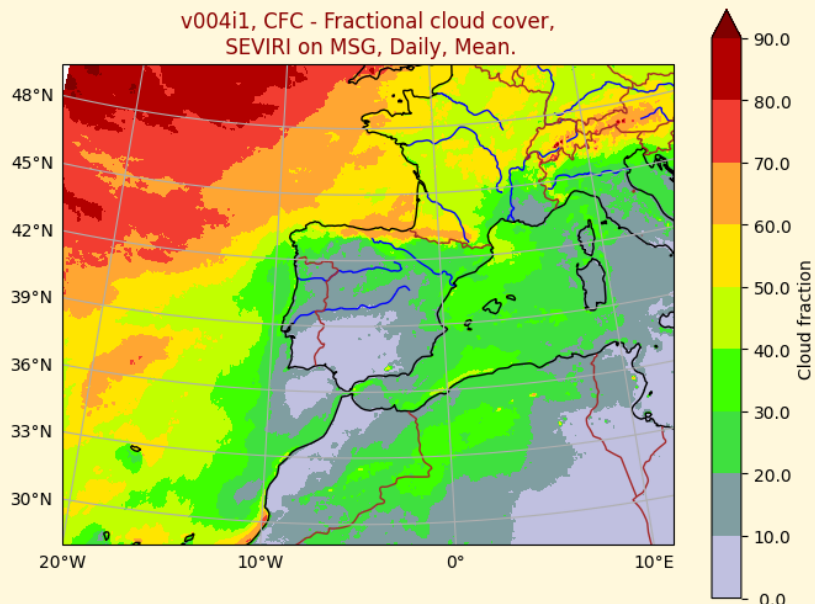
+background aerosols

- **MMR → AOD:** The *mass extinction* for each species is known
- **Distribute 11 aerosol between 4 Tegen species:**
 - *LAND* = Sulfate + Hydrophobic Organic matter + Hydrophilic Organic Matter
 - *SEA* = Sea salt bin 1 + Sea salt bin 2 + Sea salt bin 3
 - *DESERT* = Desert dust bin 1 + Desert Dust bin 2 + Desert dust bin 3
 - *SOOT* = Hydrophobic Black Carbon + Hydrophilic Black Carbon

Case 1-15 July 2023

CMSAF. 20230701
15 days mean.

v004i1, CFC - Fractional cloud cover,
SEVIRI on MSG, Daily, Mean.



Summer case over the Iberian peninsula.

- * From 1st to the 15th of July 2023.
- * Period of clear skies specially over the SW.
- * Dust intrusion between the 10th and the 12th not too strong.

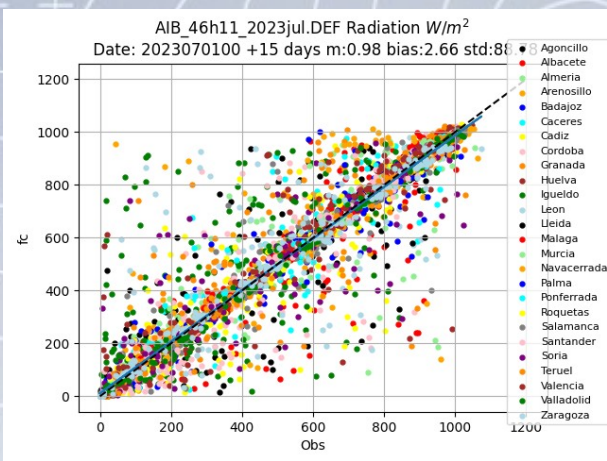
Mean Fractional cloud cover from SEVIRI on MSG for the whole period (1-15 July 2023).

Case 1-15 July 2023

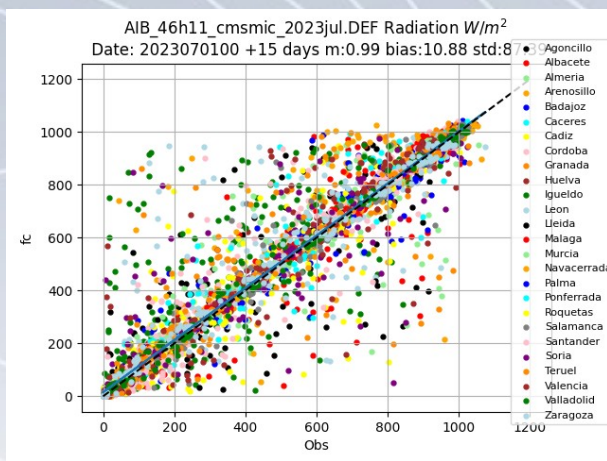


Comparison with ground observations

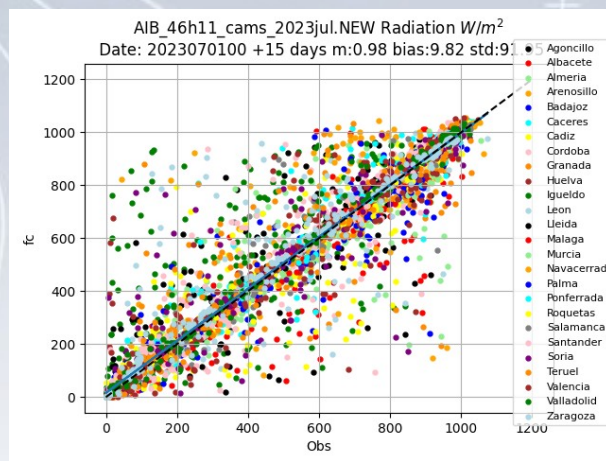
26 ground stations (25 in the peninsula + 1 in the balearic islands)
 Hourly Short Wave (SW) global radiation.



tegenaod



camscms



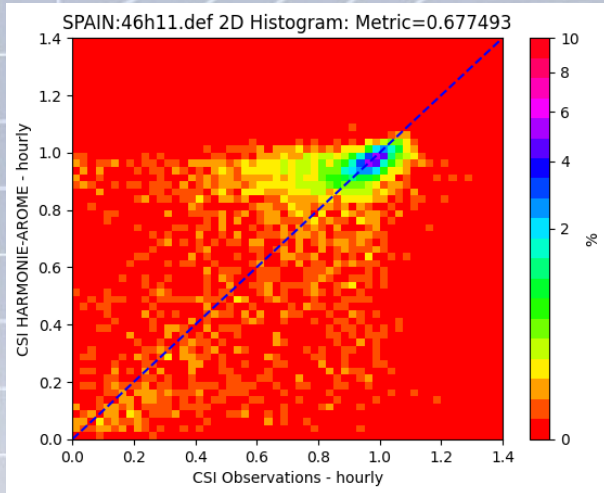
camsrnt

	tegenaod	camscms	camsrnt
bias	2.66	10.88	9.82
stdv	88.78	87.39	91.95

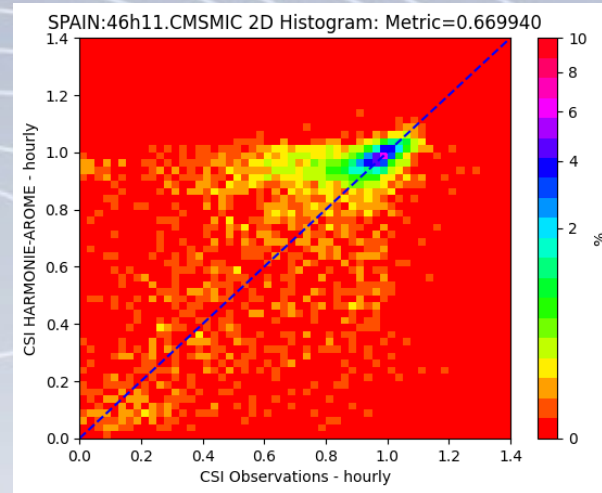
CY46h1
 5 days spin-up
 1-15 July 2023
 00Z, steprange 1-24H

Case 1-15 July 2023

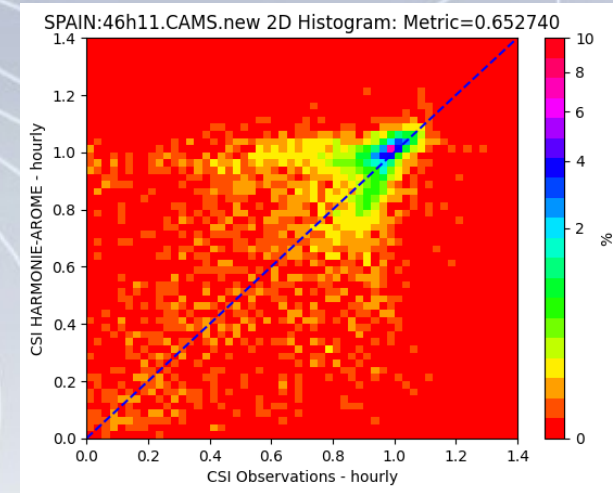
Comparison with ground observations



tegenaod



camscms



camsrnt

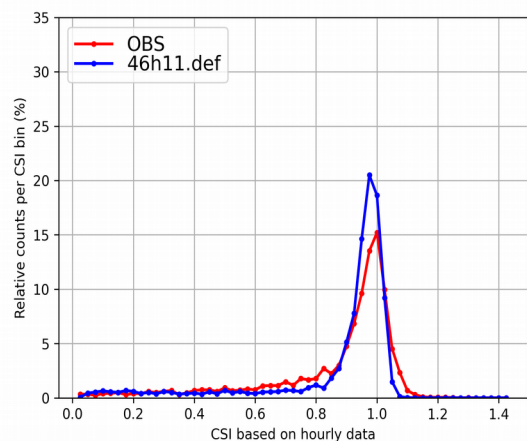
CSI (Clear Sky Index): Fraction of SW (forecasted/observed) over estimated SW clear sky radiation

2D hourly CSI histogram: CSI Harmonie vs. CSI Observation

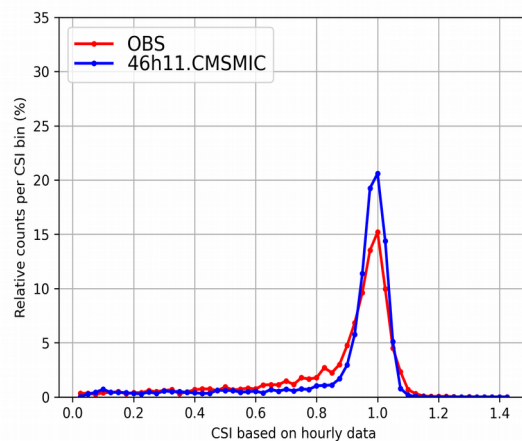
Options tegenaod and camscms give an overestimation of clear sky situations (also camsrnt but not so high)

Case 1-15 July 2023

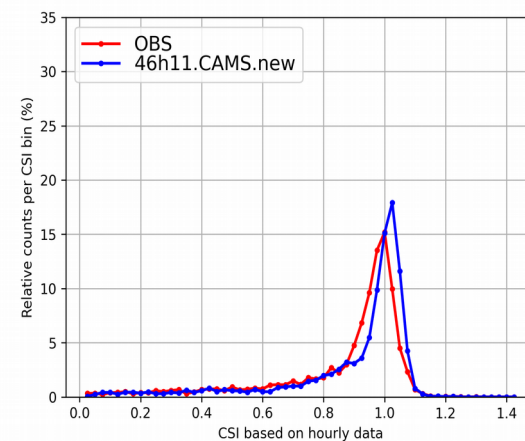
Comparison with ground observations



tegenaod



camscms



camsrnt

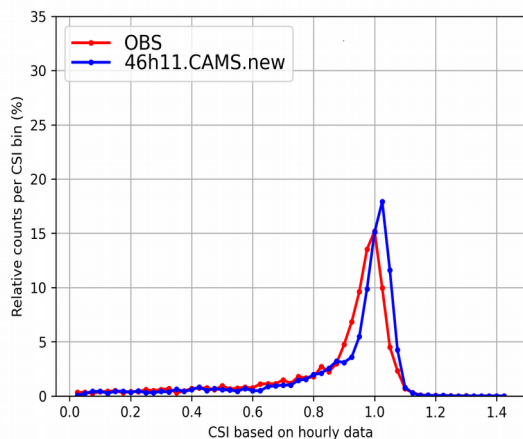
CSI (Clear Sky Index): Fraction of SW (forecasted/observed) over estimated SW clear sky radiation

Histogram: CSI Harmonie vs. CSI Observation

In the camsrnt case the maximum is not too high, but it is displaced to the high values (too much radiation in clear sky conditions)

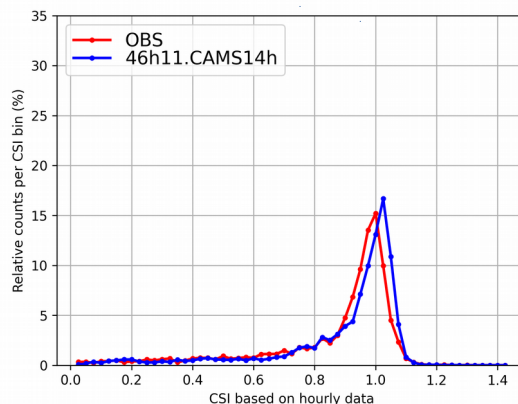
Case 1-15 July 2023

Improvement of CAMSNRT option:



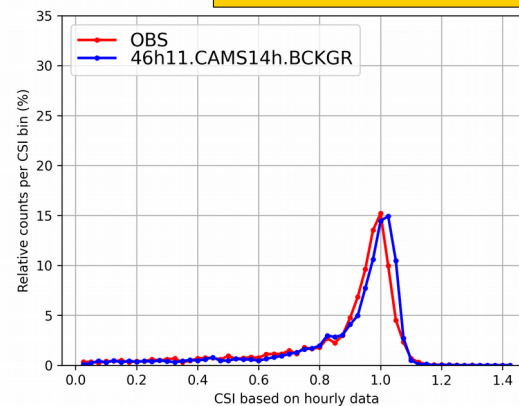
camsnrt

Adding Nitrate and Ammonia (Total of 14 aerosol species)



Adding background aerosols (NOT COMPLETELY VERIFIED)

+background aerosols

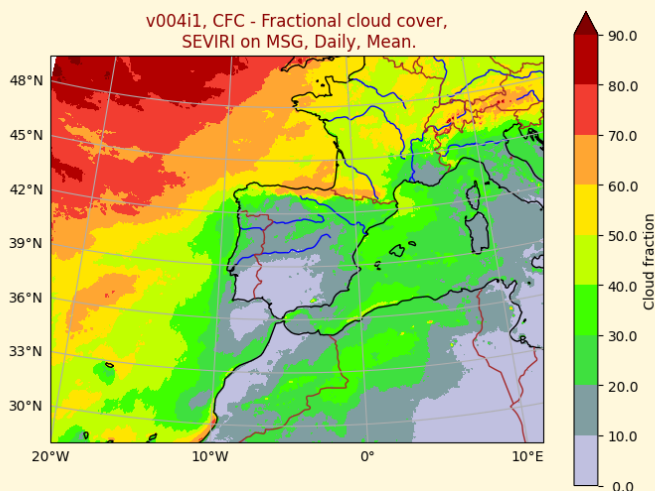


CSI (Clear Sky Index): Fraction of SW (forecasted/observed) over estimated SW clear sky radiation

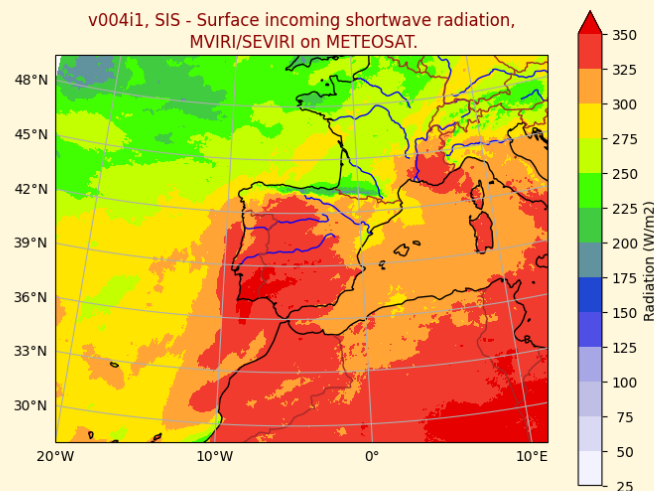
Case 1-15 July 2023.

Use of satellite products

CMSAF. 20230701
15 days mean.



CMSAF. 20230701
15 days mean.



Mean **Fractional cloud cover** from SEVIRI on MSG for the whole period (1-15 July 2023).

Mean **incoming shortwave radiation** from SEVIRI on MSG for the whole period (1-15 July 2023).

Case 1-15 July 2023.



GOBIERNO DE ESPAÑA

MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA



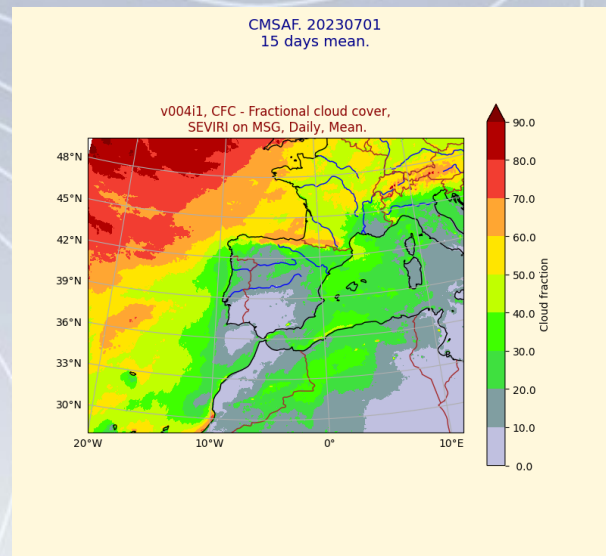
Use of satellite products

Mean **Fractional cloud cover** from SEVIRI on MSG for the whole period (1-15 July 2023).

HARMONIE-AROME:

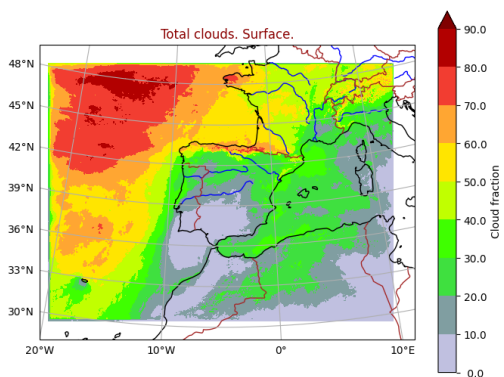
Mean total cloud cover
Time 00Z; Days 1-15 July 2023
Steprange 1-24H

**Underestimation of cloud cover over the Alps and the Morocco coast.
The three experiments give similar values.**



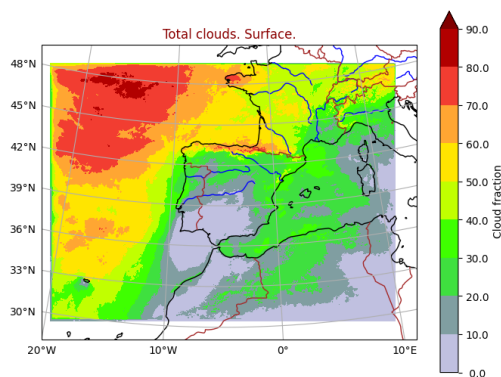
Dayly mean. AIB_001 - 024. 15 days

tegenaod



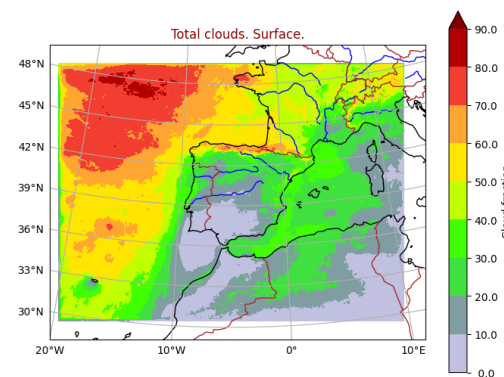
Dayly mean. AIB_46h100 + 001 - 024. 15 days

camscms



Dayly mean. AIB_46h1100 + 001 - 024. 15 days

camsrnt



Case 1-15 July 2023.

Use of satellite products

Mean **incoming shortwave radiation** from SEVIRI on MSG for the whole period (1-15 July 2023).

CMSAF_20230701
15 days mean.

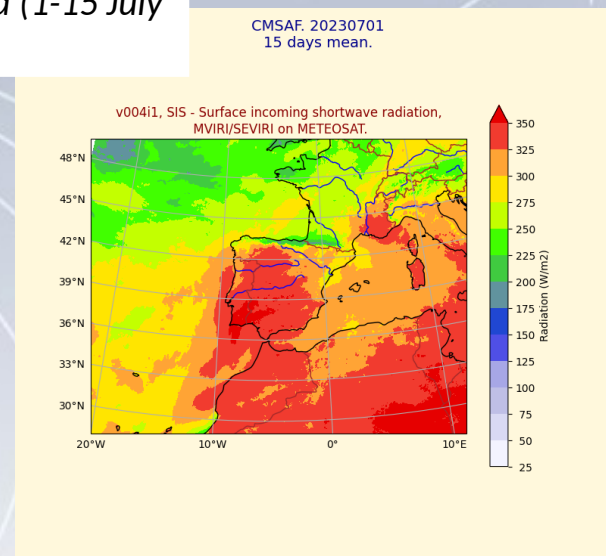
HARMONIE-AROME: CY46h1

Mean **accumulate global radiation** in 24 hours

Time 00Z; Days 1-15 July 2023

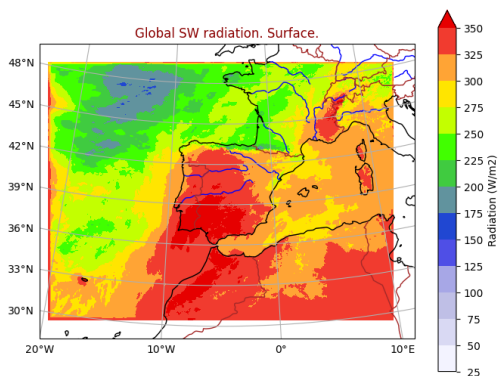
Steprange: 24H

- **Underestimation of radiation over the Saharan desert.**
- **The experiment camstr gives lower values over the north of Africa than the rest.**
- **Cloudy conditions differences in another slide.**



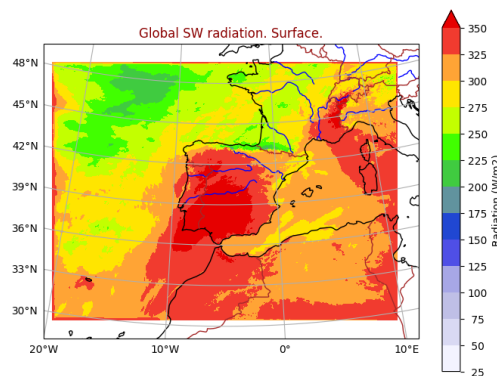
AIB_024

tegenaod



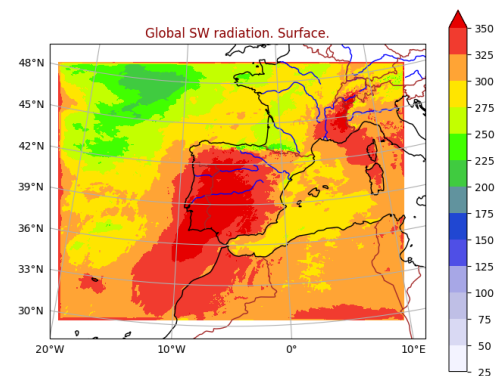
AIB_46h11_070100 + 024

camscms

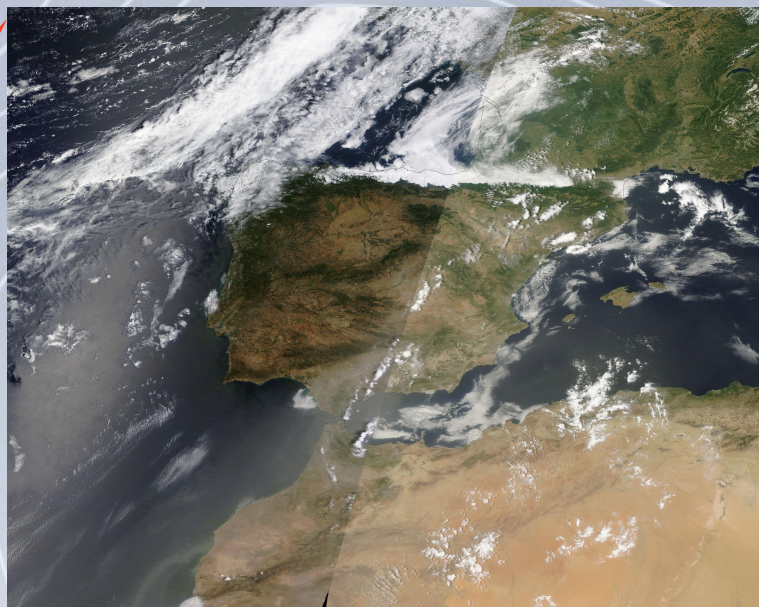
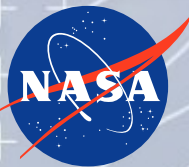


AIB_46h11_100 + 024

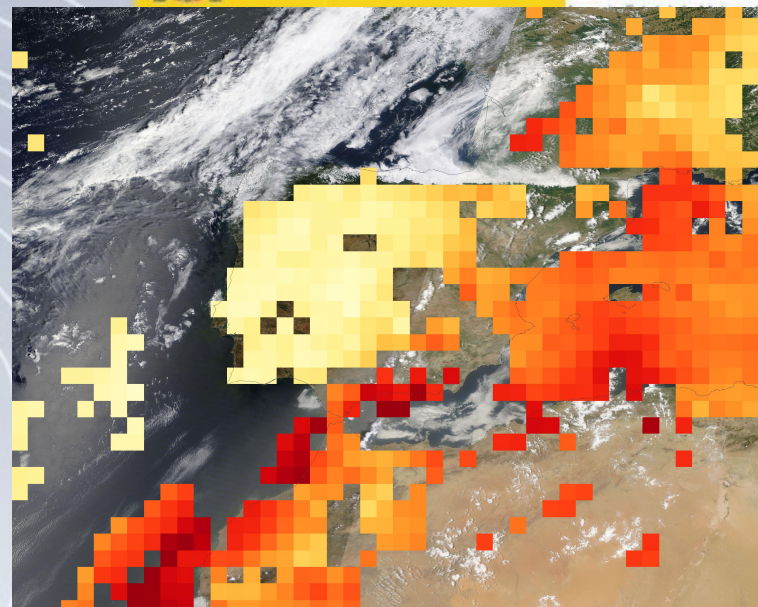
camstr



Case 1-15 July 2023. Dust intrusion: 10-12



MODIS Terra/Aqua
11/07/2023. True Color

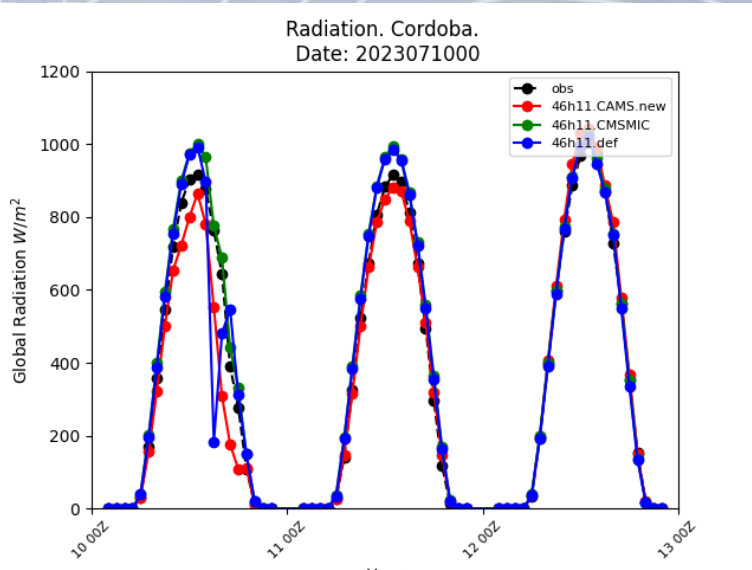
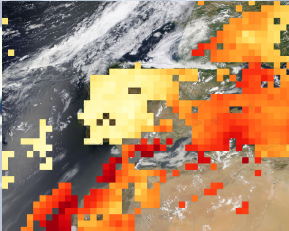


MODIS Terra/Aqua
11/07/2023. AOD

DUST INTRUSION CASE: 10-12/07/2023

NOT TOO STRONG

Case 1-15 July 2023. Dust intrusion: 10-12

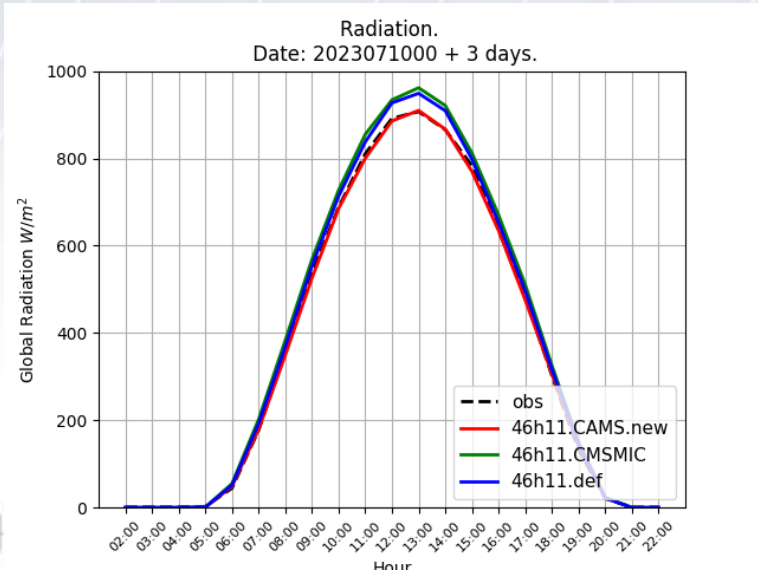
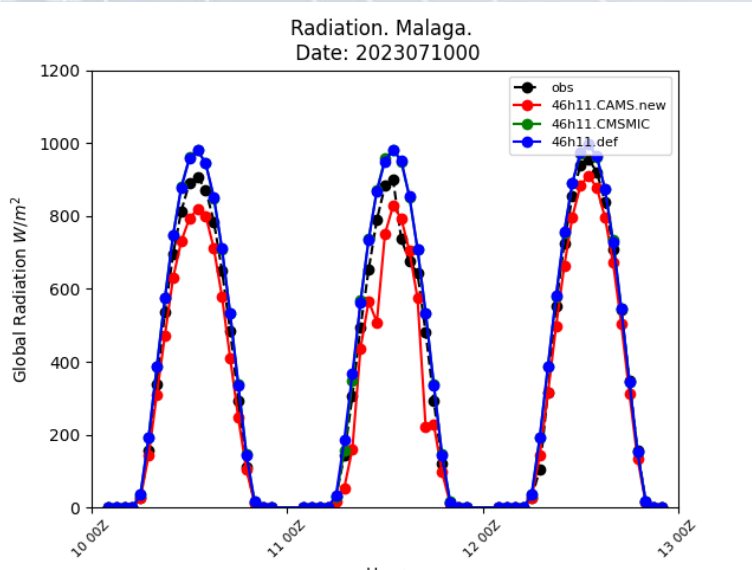


HARMONIE-AROME:

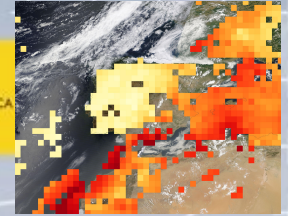
Mean accumulate global radiation in 24 hours
Time 00Z; Days 10-12 July 2023
Steprange: 24H

CAMSNRT experiment seems to overestimate the dust amount and reduce too much the radiation for some of the stations.

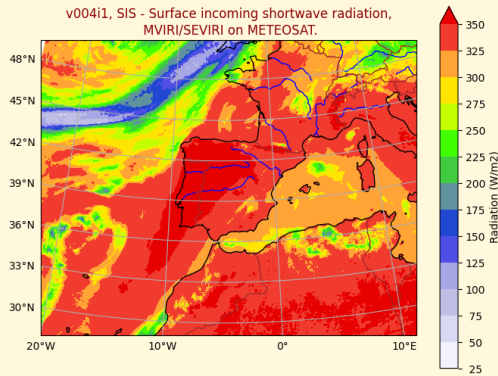
Although the mean for the period is better!



Case 1-15 July 2023. Dust intrusion: 10-12



CMSAF. 20230710



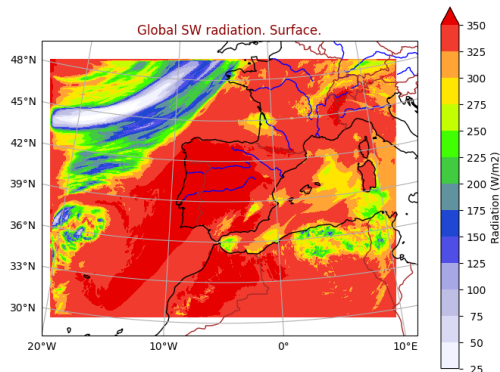
Ground observations showed that CAMSNRT was behaving all right in this case but SEVIRI product shows no reduction of radiation over land due to the dust.

Is SEVIRI getting good results in this case?

TEGEN + B

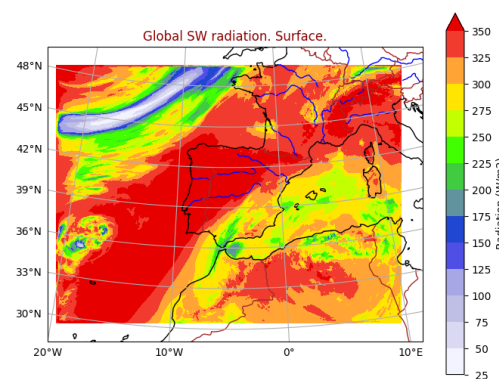
tegenaod

024



camsnrt

024



CLOUD DROPLETS

- Configurations:
 - Old configuration (CY 40) constant values over sea, land and urban terrain.
 - Present configuration (default from CY43h2) vertical dependence.
 - CAMS aerosols (alternative from CY46h1)
- Comparison Present configuration vs. CAMS
- Radiation scheme
- Measurement campaign

CLOUD DROPLETS

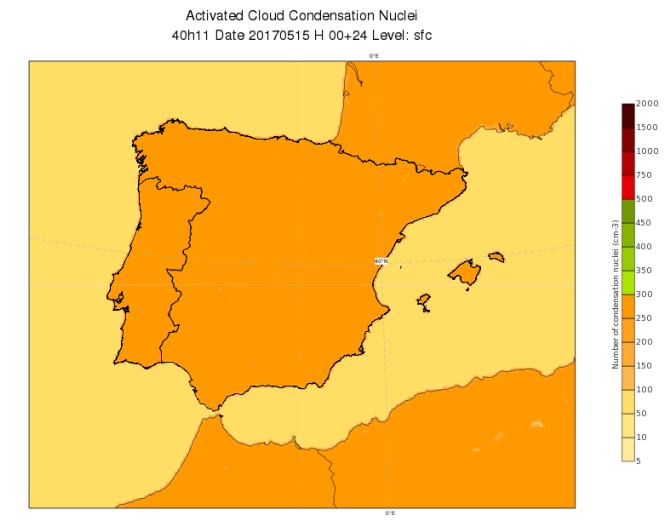
Cloud droplet number concentration is used in:

- Radiation scheme: Calculation of effective radius.
- Microphysics:
 - Sedimentation (Calculation of vertical velocity)
 - Autoconversion (LKOGAN=TRUE)
 - Collision of cloud droplets (LOCND2=TRUE)
 - Riming by cloud droplets (LOCND2=TRUE)

OLD CLOUD DROPLET configuration. until CY40

CY40:

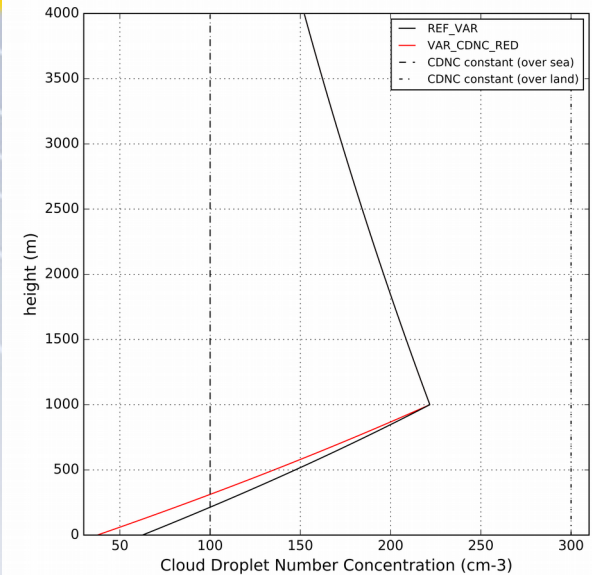
- 100cm⁻³ over sea, 300cm⁻³ over land and 500cm⁻³ over urban areas.
- No vertical variation
- Inconsistency with the radiation scheme



CLOUD DROPLETS

Present configuration from CY43h2

- From CY43h2, the CDNC has a vertical dependence that can be adjusted by 3 parameters (table).
- Used also in the IFS radiation scheme.
- It reduces the fog over sea as a lower CDNC increases the sedimentation and helps the dissipation.
- The problem with stratiform precipitation coming from the sea to the land disappearing at the coast is solved.
- Activation:
 - USEAERO=tegenaod
 - USEAERO=camsnrt/camscms + LAEROMIC=FALSE



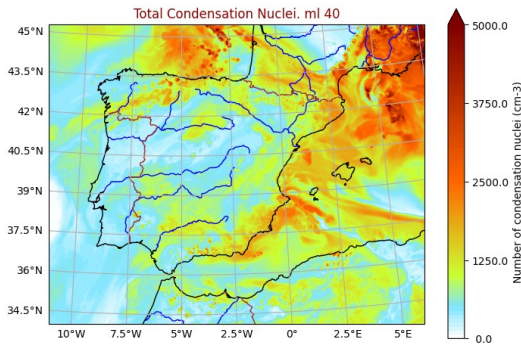
Parameter	Default value	Description
RFMIN(26)	250E6	If > 0.01 , it replaces default CDNC everywhere. So $RFRMIN(26)=50E6$ (Beware of that it is in m^{-3} !) gives $CDNC = 50 \text{ cm}^{-3}$ at reference level (1000 hPa) and $RFRMIN(26) \times \text{pressure} / \text{ref-pressure}$ elsewhere.
RFMIN(22)	0.25	Tuning parameter for CDNC at lowest model level . Lower value give lower CDNC. $RFRMIN(22)=0.5$ means $CDNC = \text{old CDNC} \times 0.5$.
RFMIN(29)	1000.	If > 0 . and $RFRMIN(22) > 0$ it gives the upper limit in metres for which the reduction of CDNC has an effect. A linear decrease from the lowest level to $RFRMIN(29)$ metres is assumed

CLOUD DROPLETS

From CAMS aerosols

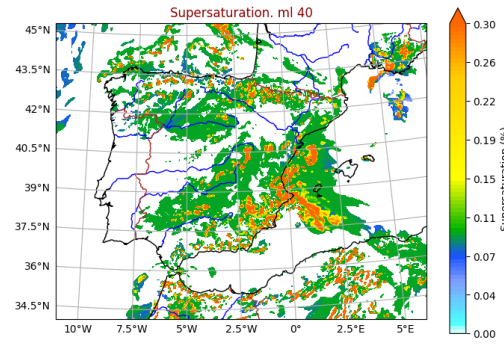
- In CY46h1 is possible to use cloud droplets from CAMS aerosols
- **USEAERO = camsnrt/camscoms + LAEROMIC=TRUE**
- Namelist: NAMNRTAER
 - **SSMINLO** = 0.05E-2 (MINimum in-cloud SuperSaturation in LOwer level)
 - **SSMINUP** = 0.10E-2 (MINimum in-cloud SuperSaturation in UPper levels)
 - **CLDROPMIN** = 10.0E6 (MINimum CLOUD DROplet concentration in m-3)
- Increasing SSMINLO and SSMINUP permits to increase the activation of condensation nuclei and Cloud droplets concentration.

AIB_46h11_cams_2022mar.DEF. 2022030600 + 012



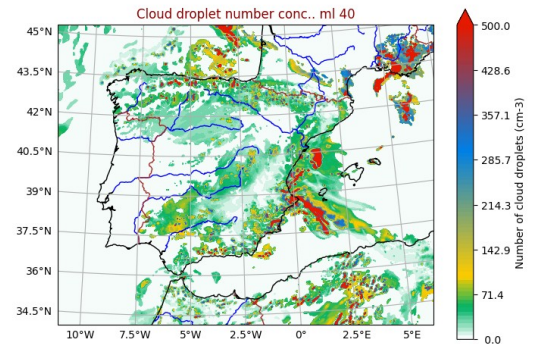
Cloud nuclei concentration

AIB_46h11_cams_2022mar.DEF. 2022030600 + 012



Supersaturation

AIB_46h11_cams_2022mar.DEF. 2022030600 + 012

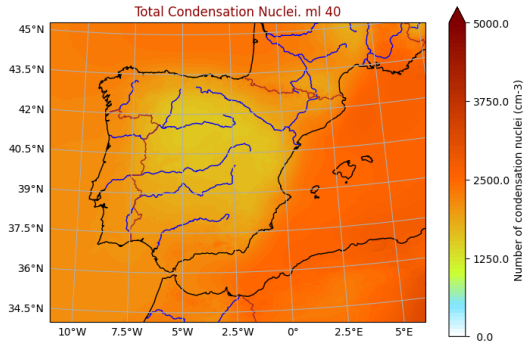


Cloud droplets

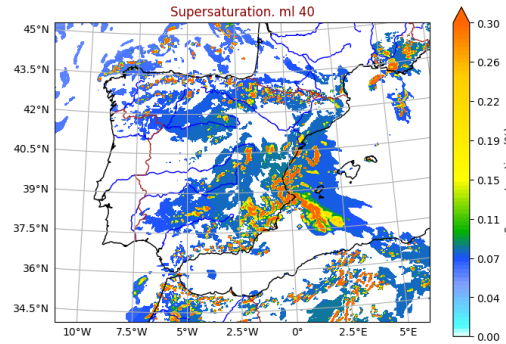
CLOUD DROPLETS

From CAMS aerosols. **TOP ROW: Climatology. BOTTOM: Near real time.**

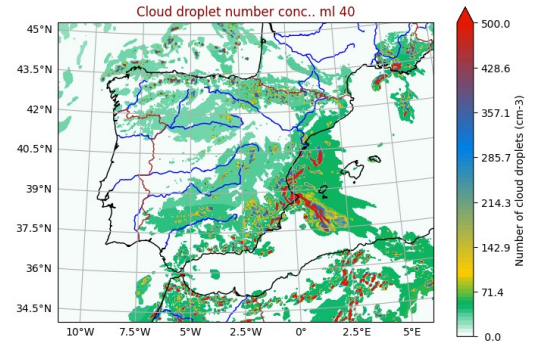
AIB_46h11_cmsmic_2022mar.DEF. 2022030600 + 012



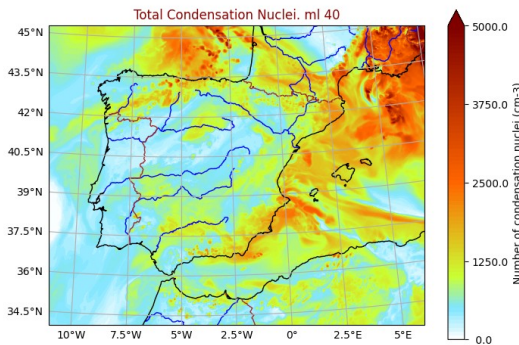
AIB_46h11_cmsmic_2022mar.DEF. 2022030600 + 012



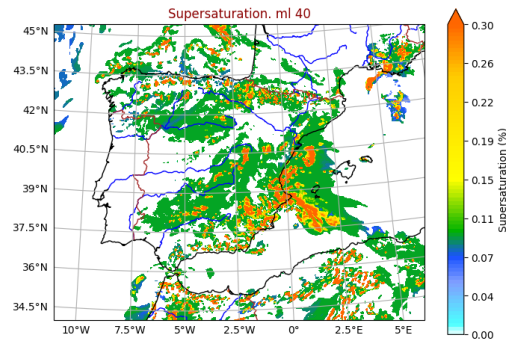
AIB_46h11_cmsmic_2022mar.DEF. 2022030600 + 012



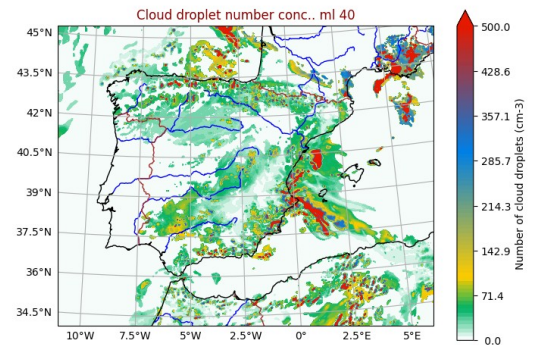
AIB_46h11_cams_2022mar.DEF. 2022030600 + 012



AIB_46h11_cams_2022mar.DEF. 2022030600 + 012



AIB_46h11_cams_2022mar.DEF. 2022030600 + 012



Cloud nuclei
concentration

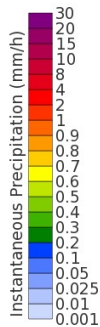
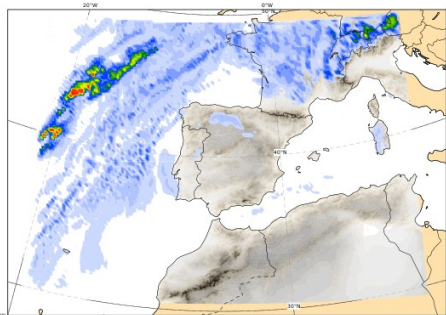
Supersaturation

Cloud droplets

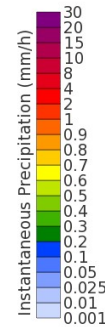
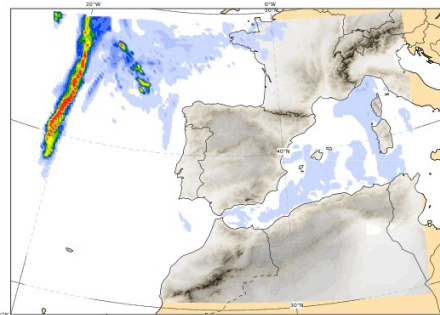
CLOUD DROPLETS



Instantaneous rain (mm/h)
devCY46h1.CAMS. Date: 2021122912 + 012 Level: 65



Instantaneous rain (mm/h)
devCY46h1.CAMS. Date: 2021122912 + 048 Level: 65

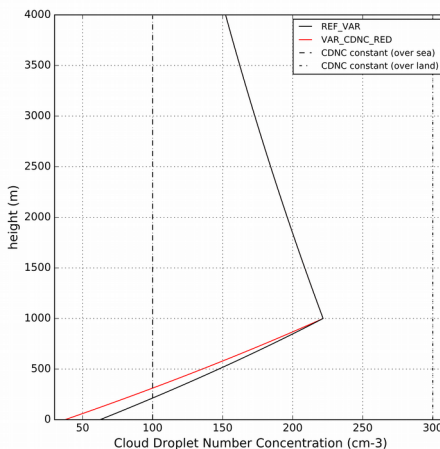
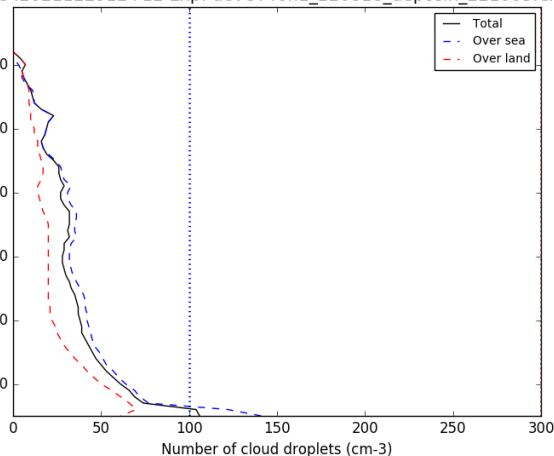


Default cloud droplets.
Vertical distribution.

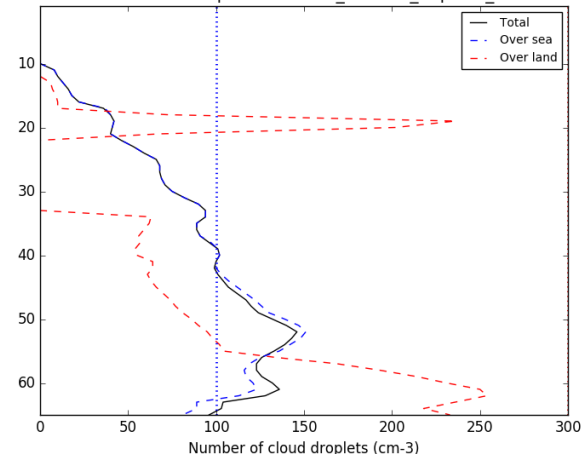
Light precipitation is
dominant

Strong precipitation is
dominant

Cloud droplet number conc.
Date :2021122912+12 Exp: devCY46h1_220818_deposin_221003.CAMS



Cloud droplet number conc.
Date :2021122912+48 Exp: devCY46h1_220818_deposin_221003.CAMS



Cloud droplet number concentration from n.r.t. CAMS

CLOUD DROPLETS. Case 1-15 July 2023.

Use of satellite products

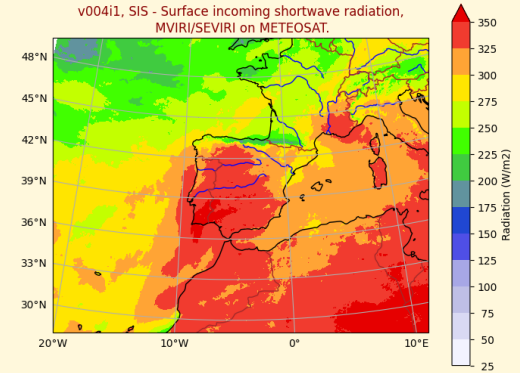
Mean **incoming shortwave radiation** from SEVIRI on MSG for the whole period (1-15 July 2023).

CMSAF. 20230701
15 days mean.

Cloudy conditions, NW of the domain over the Atlantic:

- **camsnrt and camscms higher radiation over the atlantic ocean.**
- **The cloud droplet number concentration is lower than in the case of tegenaod.**

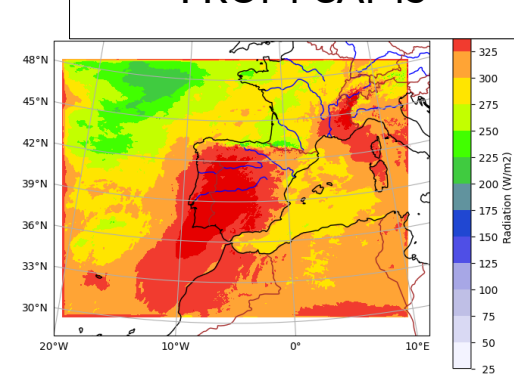
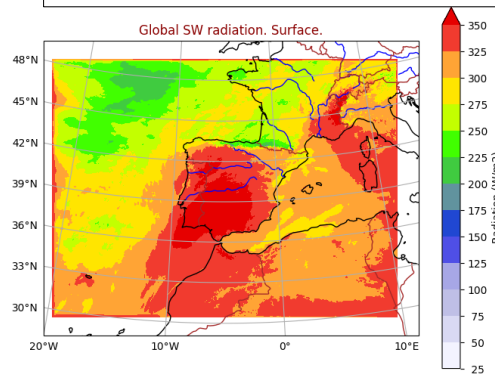
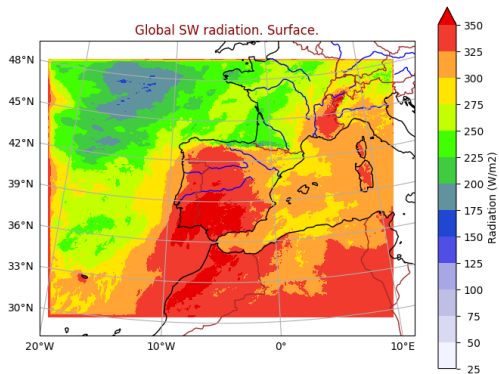
v004i1, SIS - Surface incoming shortwave radiation, MVIRI/SEVIRI on METEOSAT.



Tegenaod
+DEFAULT CDNC
PROFILE

camscms +DROPLETS
FROM CAMS

camsnrt + DROPLETS
FROM CAMS



NASA Worldview

Layers Events Data

OVERLAYS

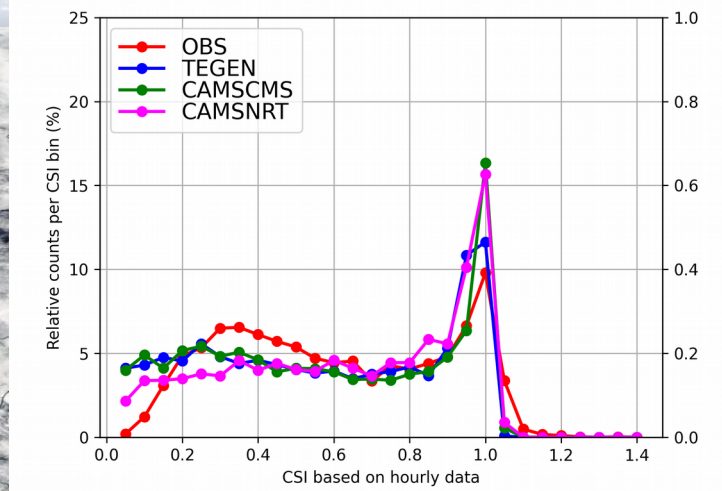
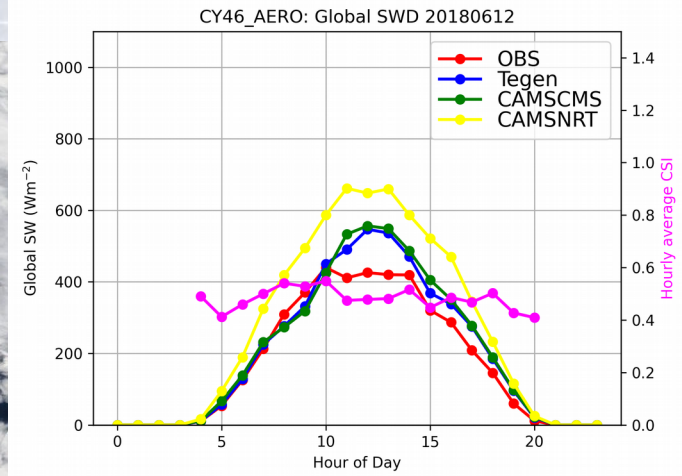
- Place Labels
Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community
- Coastlines / Borders / Roads
© OpenStreetMap contributors
- Coastlines
© OpenStreetMap contributors

BASE LAYERS

- Corrected Reflectance (True Color)
NOAA-21 / VIIRS
- Corrected Reflectance (True Color)
NOAA-20 / VIIRS
- Corrected Reflectance (True Color)
Suomi NPP / VIIRS
- Corrected Reflectance (True Color)
Aqua / MODIS
- Corrected Reflectance (True Color)
Terra / MODIS v6.1 STD

+ Add Layers Group Similar Layers

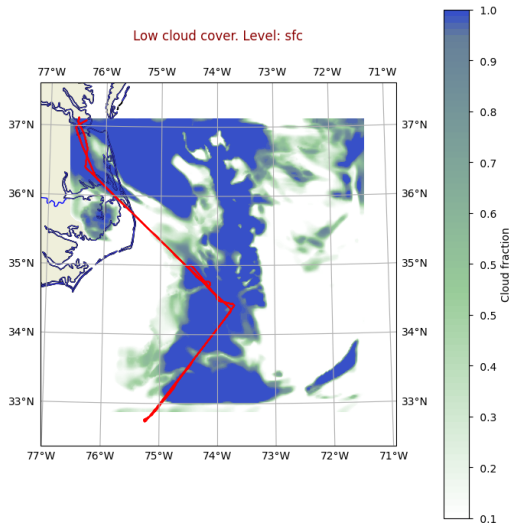
Start Comparison



Period: 20180601-15
Irish Domain

- Stratocumulus covering Ireland
- CAMSNRT overestimate the radiation more than CAMSCMS and tegen, probably due to an underestimation of cloudiness (see CSI plot between 0.2 and 0.6)
- The lack of clouds increases the clear sky hours (higher values for CSI=1.0)
- Revision of statistical cloud scheme?

46h11.t02.CAMS. 2020030600 + 018



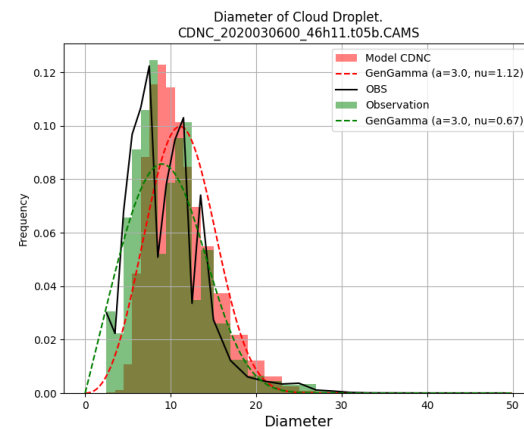
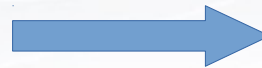
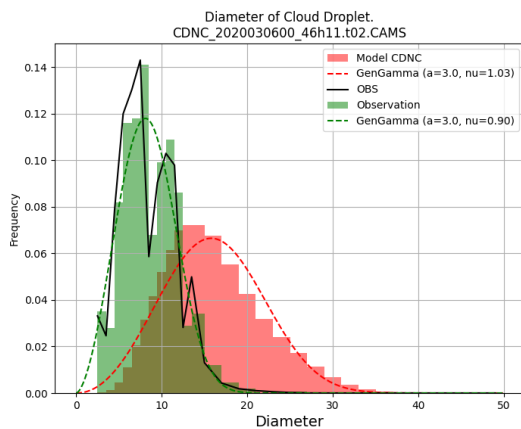
Cloud droplet size distribution plots in the bottom:

- * **red: model**
- * **green: observations**

Left bottom: old code and SSMINUP=0.8

Right bottom: new code and SSMINUP=1.0

Low cloud cover from HARMONIE-AROME model.
Date 20200306 H+18
Aircraft trajectory in red



Conclusions.

- **Aerosol options:**
 - **tegenaod:** AOD tegen climatology
 - overstimation of clear sky situations
 - clear sky radiation is good when the situations are not far from climatology.
 - too much radiation in cloudy conditions.
 - **camscms:** Aerosol climatic MMR (mass mixing ratios)
 - overstimation of clear sky situations.
 - clear sky radiation is good when the situations are not far from climatology.
 - Good behaviour in cloudy conditions but problems in stratiform situations.
 - **camsrnt:** Near real time aerosols from CAMS.
 - Better estimation of clear sky situations.
 - clear sky radiation is too high (more aerosols are needed?)
 - Better behaviour in situations far from climatology.
 - Good behaviour in cloudy conditions but problems in stratiform situations.

Thank you for your attention