ACCORD-AROME aerosol studies

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Murcia 19 Feb 2021 towards south. Photo Jakob Lödjquist

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Near-real-time aerosols for ACCORD AROME

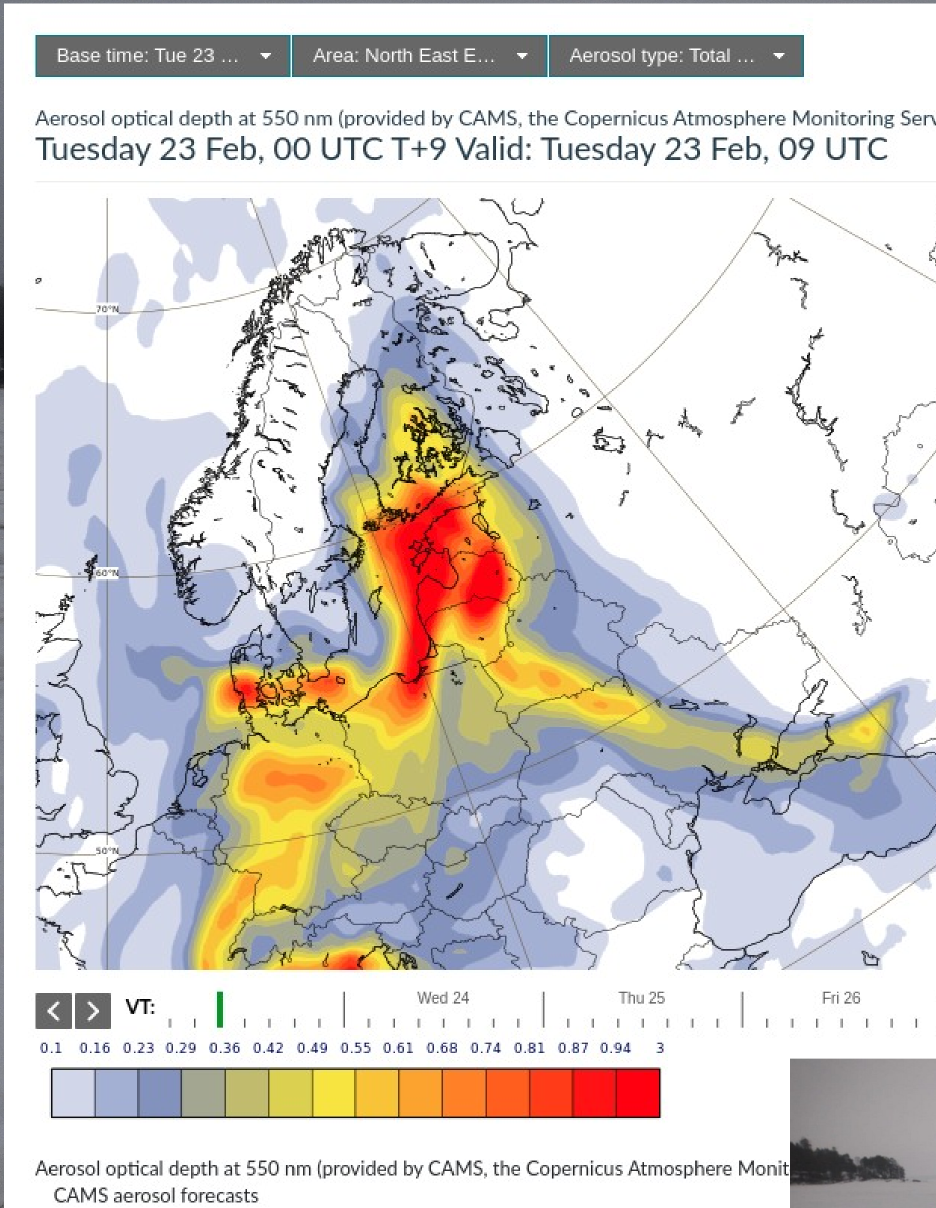
HARMONIE-AROME with ICE3 microphysics

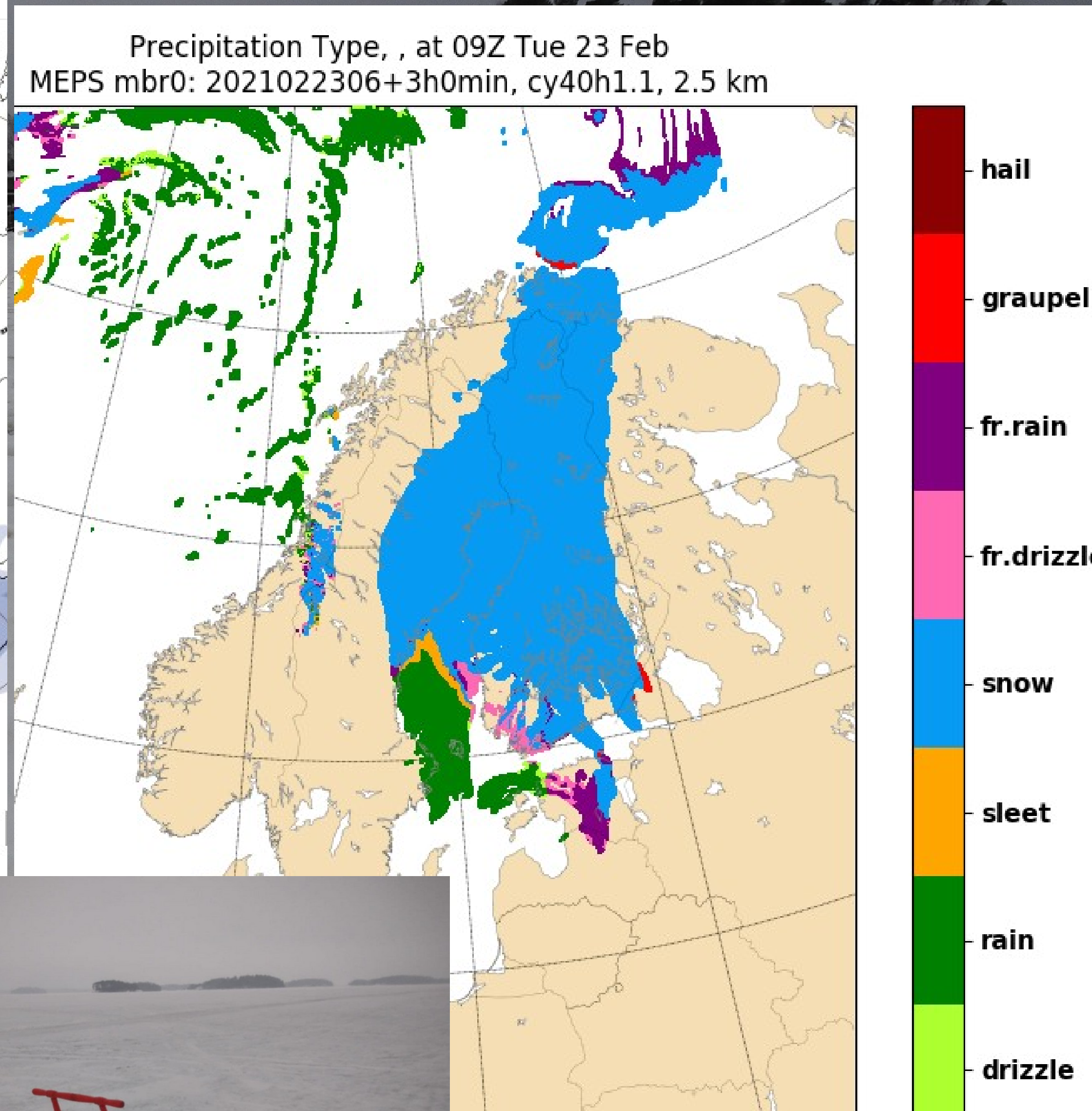
MF-AROME with LIMA microphysics

Outlook and conclusions

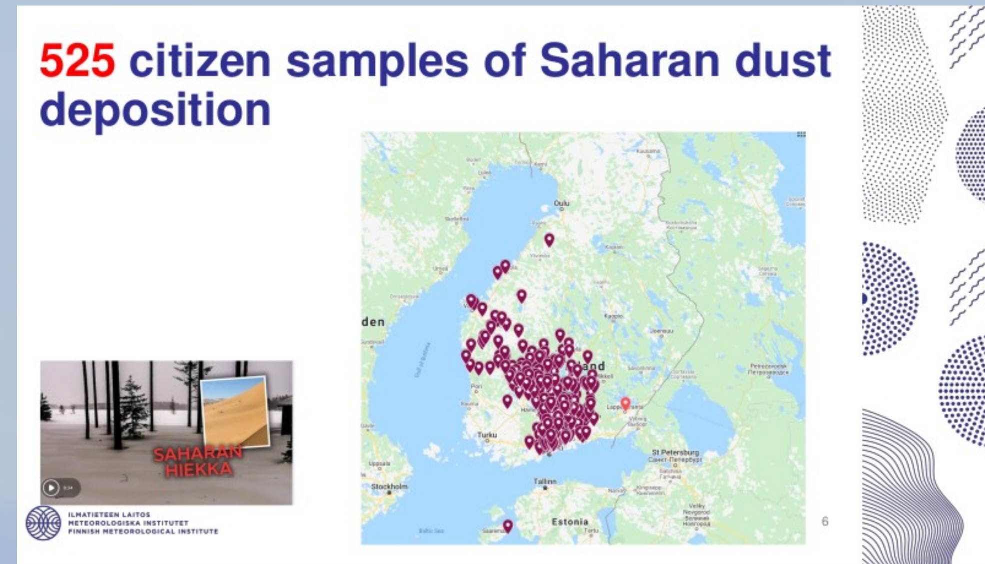

From Sahara to Helsinki
20210225 15UTC melting snow on sea ice, Helsinki

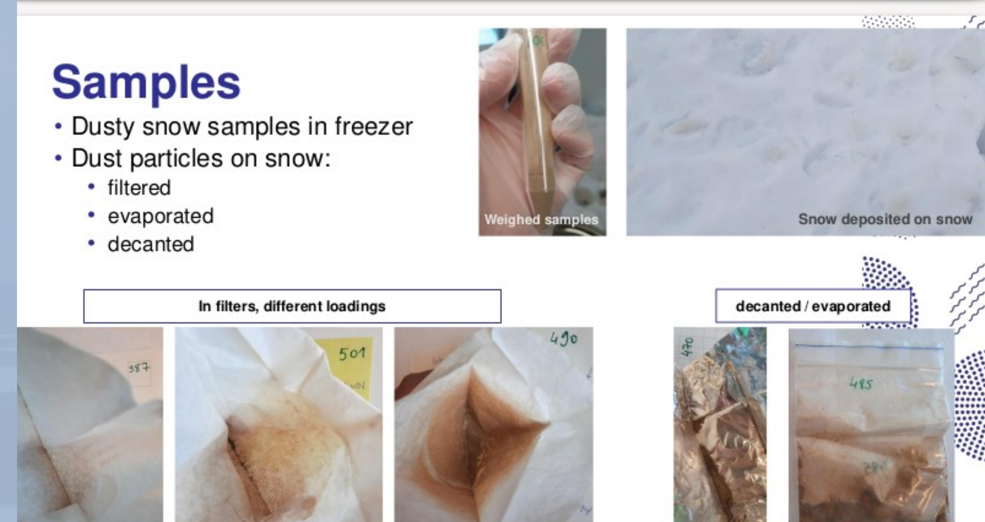
20210223 09UTC





Aerosol MMRs for cloud microphysics parametrizations

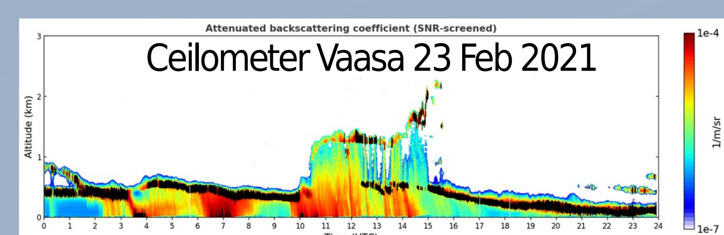




FMI requested people to collect a cup of snow with Saharan dust, filter it by a coffee filter and send to researchers for analysis and to be studied in nucleation chamber. They got 525 citizen samples. Studies are ongoing.

Courtesy of outi.meinander@fmi.fi

This case is interesting from the point of view of cloud microphysics parametrizations. Unfortunately, it was too cloudy and too little SW radiation to estimate accurately the aerosol optical depth based on radiation measurements.



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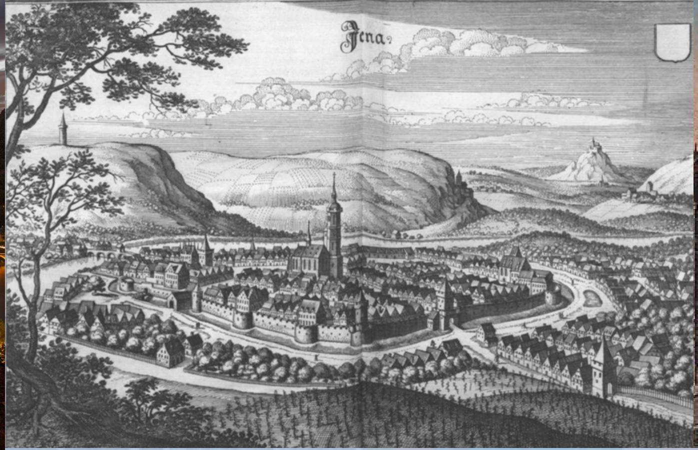
ECMWF


ECMWF
RELOCATING DUCKS



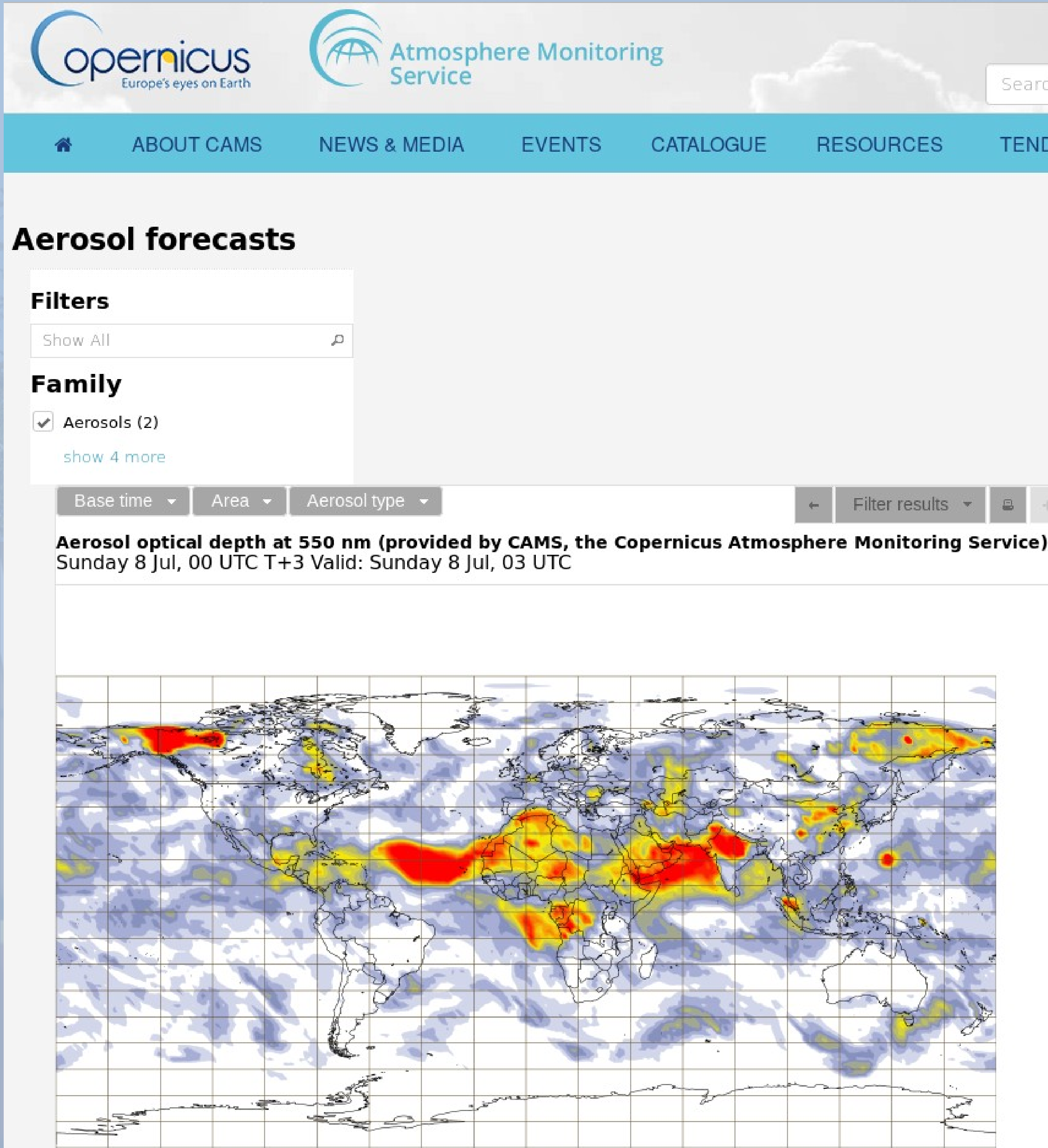
Tegen aerosol since 2004

* 2D monthly global climatology of land, sea, urban, desert aerosol optical depth at 550 nm (AOD550)

* Used for radiation only

* Combined with hard-coded aerosol inherent optical properties to obtain AOD, SSA and asymmetry factor as a function of 6 SW + 6 LW wavelengths (with fixed humidity)

Tegen, I., Hoorig, P., Chin, M., Fung, I., Jacob, D., and Penner, J.: Contribution of different aerosol species to the global aerosol extinction optical thickness: Estimates from model results, J. Geophys. Res., 102, 23895–23915, 1997.



Aerosol data available from CAMS

Climatology and
Near-real-time
3D or 2D integrated

Mass mixing ratio
(x,y,z)

Inherent optical properties:
mass extinction, single scattering albedo, asymmetry factor as functions of wavelength, humidity and aerosol species

CAMS aerosol usage in ACCORD climatology and/or n.r.t. comparison

clim
developing

Climatology
resolution 2.5 deg

2D integrated

MMR
(x,y,z) for 11 species

IOPs
ME, SSA, ASY
(14+16 λ, RH, 11 species)

Radiation (and clouds)

Made in climate generation

n.r.t.
developing

Near-real-time
resolution 0.5 deg

3D and 2D integrated

MMR
(x,y,z) for 14 species

IOPs
ME, SSA, ASY
(14+16 λ, RH, 14 species)

Radiation and clouds

Imported via boundaries

Aerosol MMRs for cloud microphysics parametrizations

HARMONIE-AROME
with ICE3 microphysics

Meteo France-AROME
with LIMA microphysics

CAMS real-time 3D mass mixing ratio of aerosol in HARMONIE-AROME

Aerosol Mass mixing ratios are advected by the dynamics of the model

Aerosol removal processes are parametrized.

Aerosol Mass mixing ratios → Nuclei concentration → Activated nuclei (CCN)

- Activated nuclei are used in the default microphysics scheme (ICE3):
  - Autoconversion (Kogan)
  - Cloud droplet sedimentation
  - Collision of cloud liquid

Aerosol mass mixing ratios are converted to optical depth@550nm and used directly by the radiation schemes of the model.

- (Aerosol inherent optical properties for different wavelengths are prescribed by the ECMWF)

CAMS real-time 3D mass mixing ratio of aerosol in HARMONIE-AROME

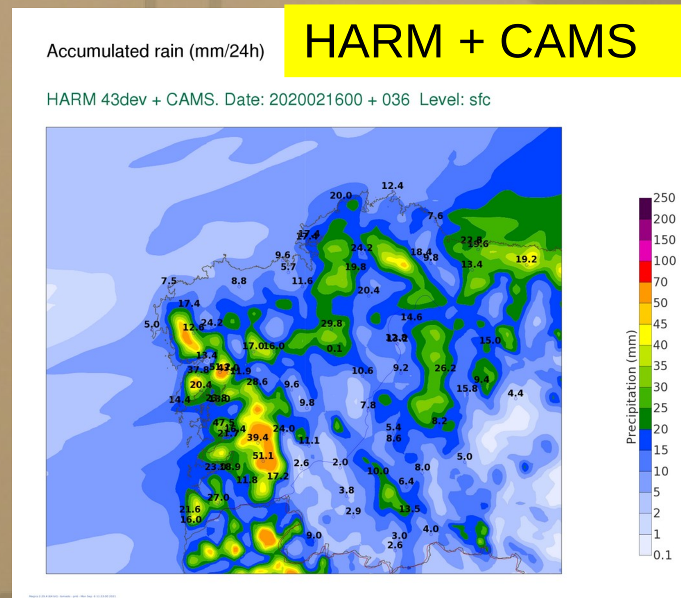
Accumulated rain 17Feb20

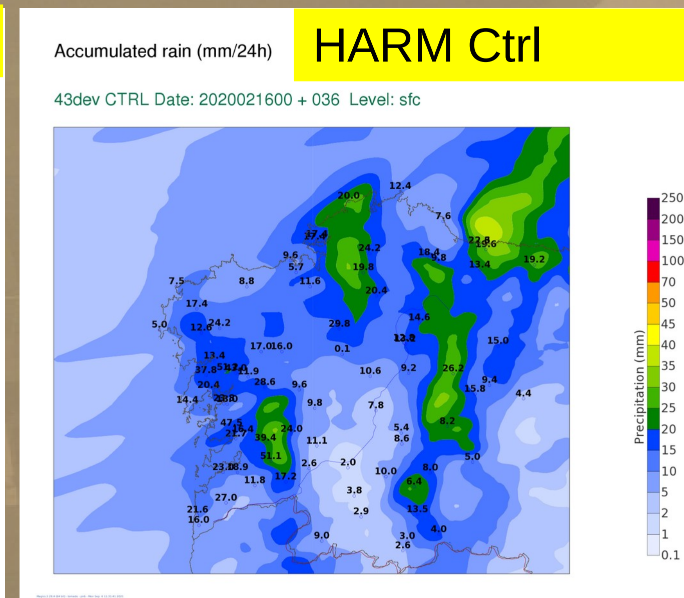
Impact on Precipitation.

In general the CCN number concentration is lower than the default values of the model.

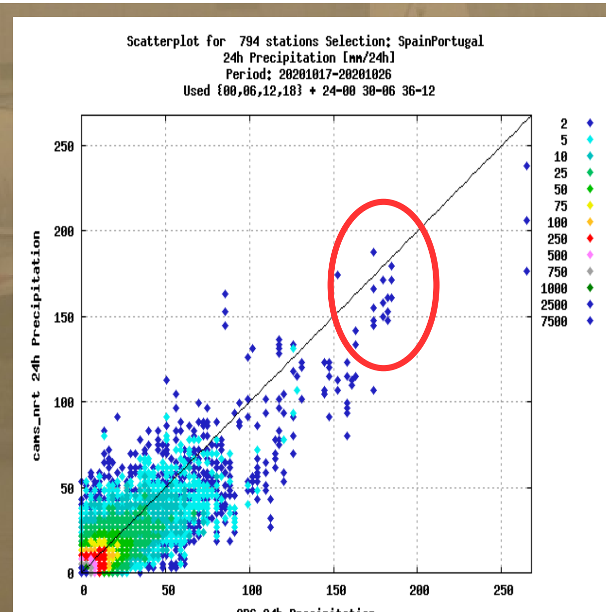
Increase of the precipitation when nrt aerosols are used.

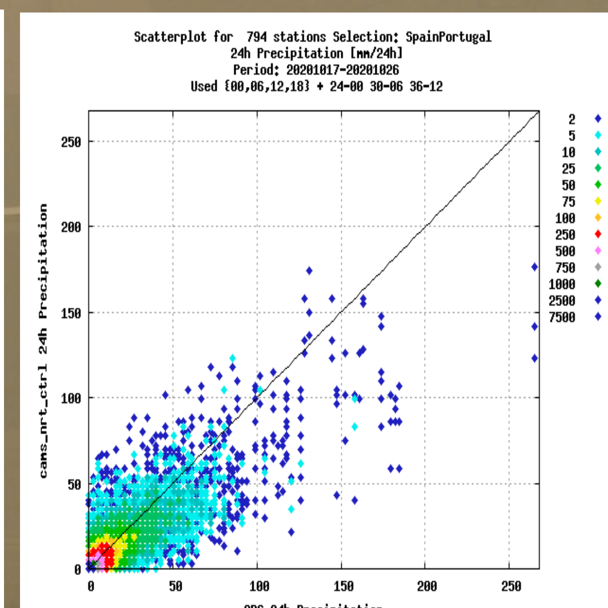
Specially important in high precipitation events.





Scatterplot
24h Precipitation
Period 20201017-20201026





CAMS real-time 3D mass mixing ratio of aerosol in HARMONIE-AROME

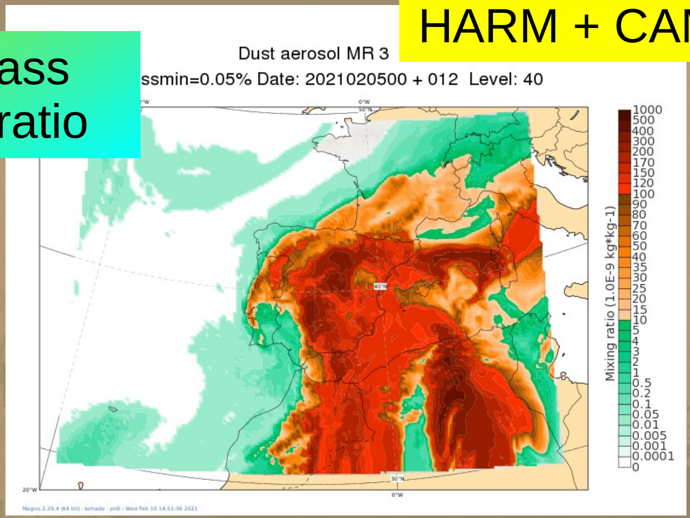
Impact on Radiation

The use of nrt aerosols permit a better SW radiation forecast during dust events.

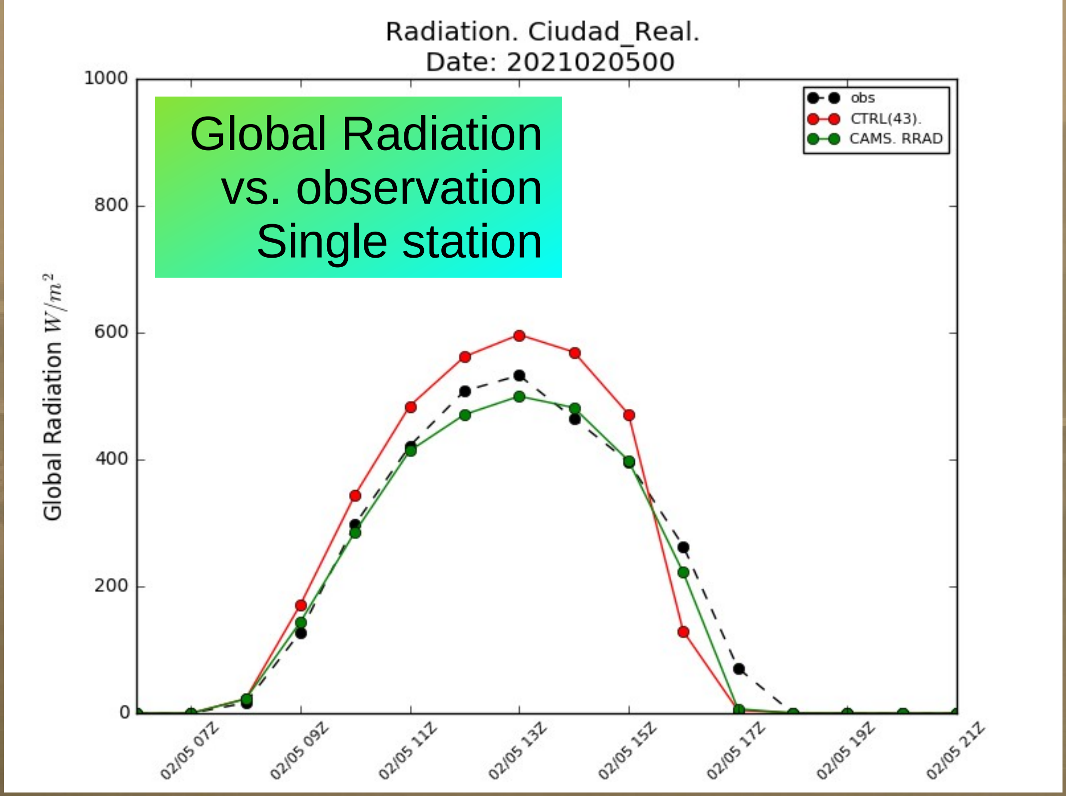
Case:20210205

HARM + CAMS

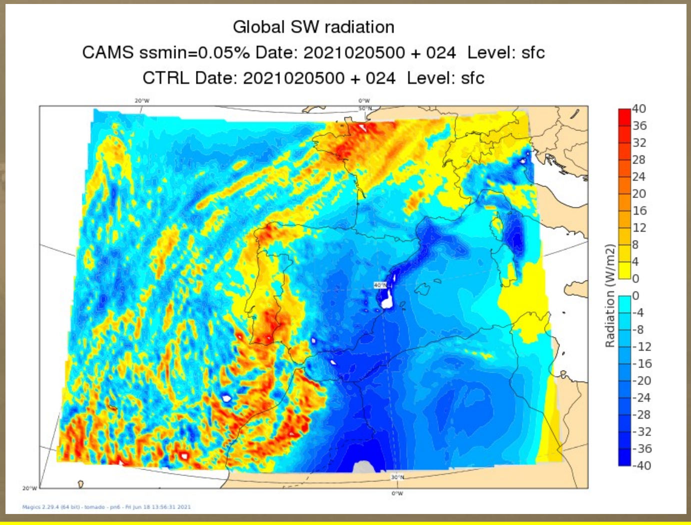
Dust Mass mixing ratio



Global Radiation vs. observation Single station



Global Radiation



(HARM + CAMS) – (HARM ctrl)

CAMS real-time 3D mass mixing ratio of aerosol in HARMONIE-AROME

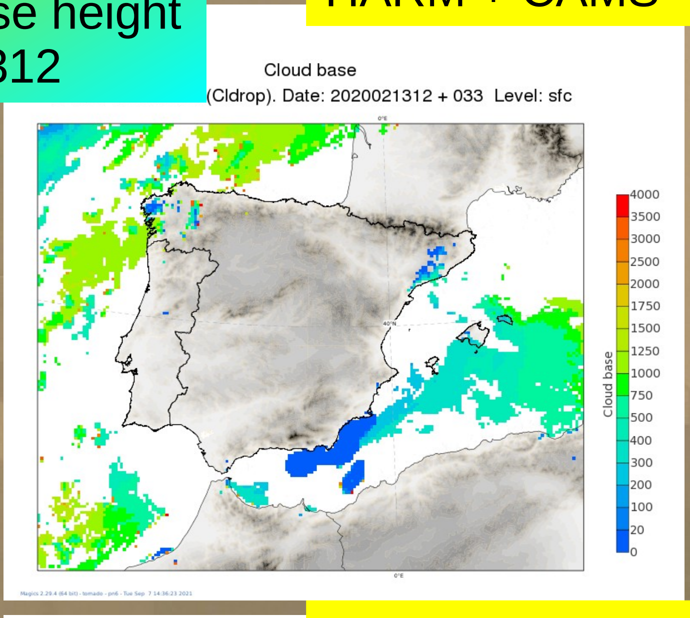
Impact on fog

The use of CAMS aerosols often have a positive impact on fogs, especially when the cloud droplet concentration is lower than by model default.

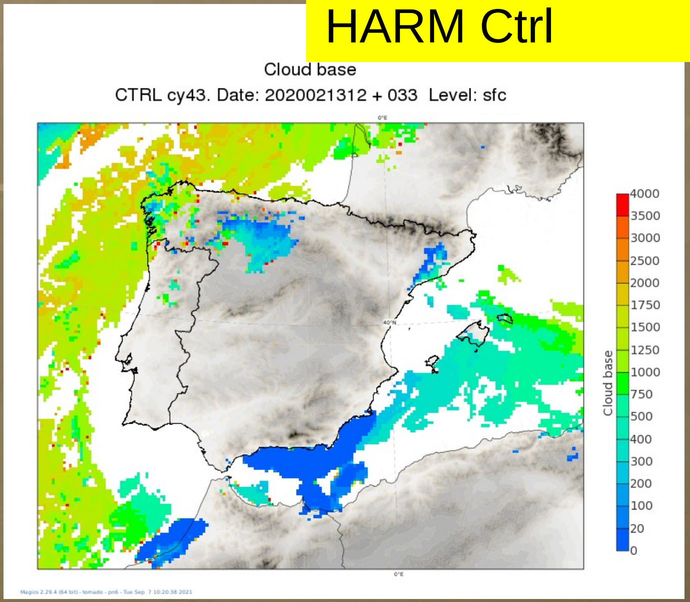
It also reduces the anomalous fogs that sometimes appear over sea. (Although this problem might be related with a wrong cloud droplet distribution in these cases)

Cloud base height
2020021312

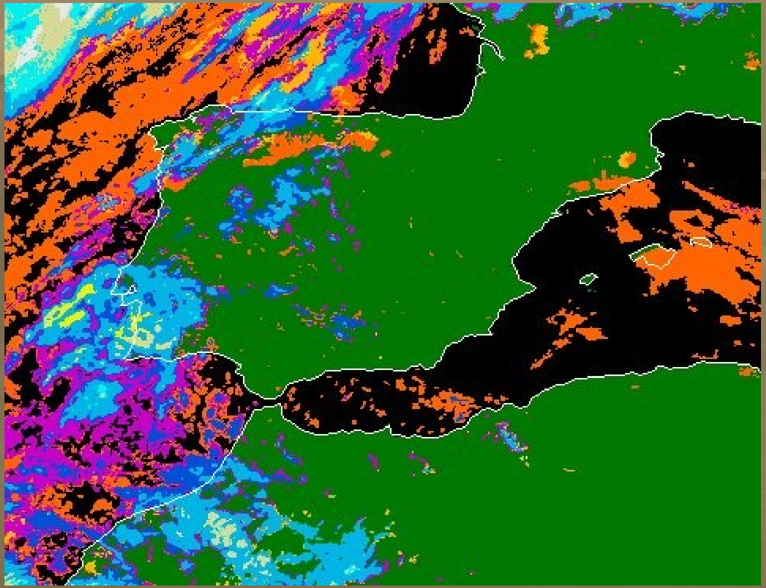
HARM + CAMS



HARM Ctrl



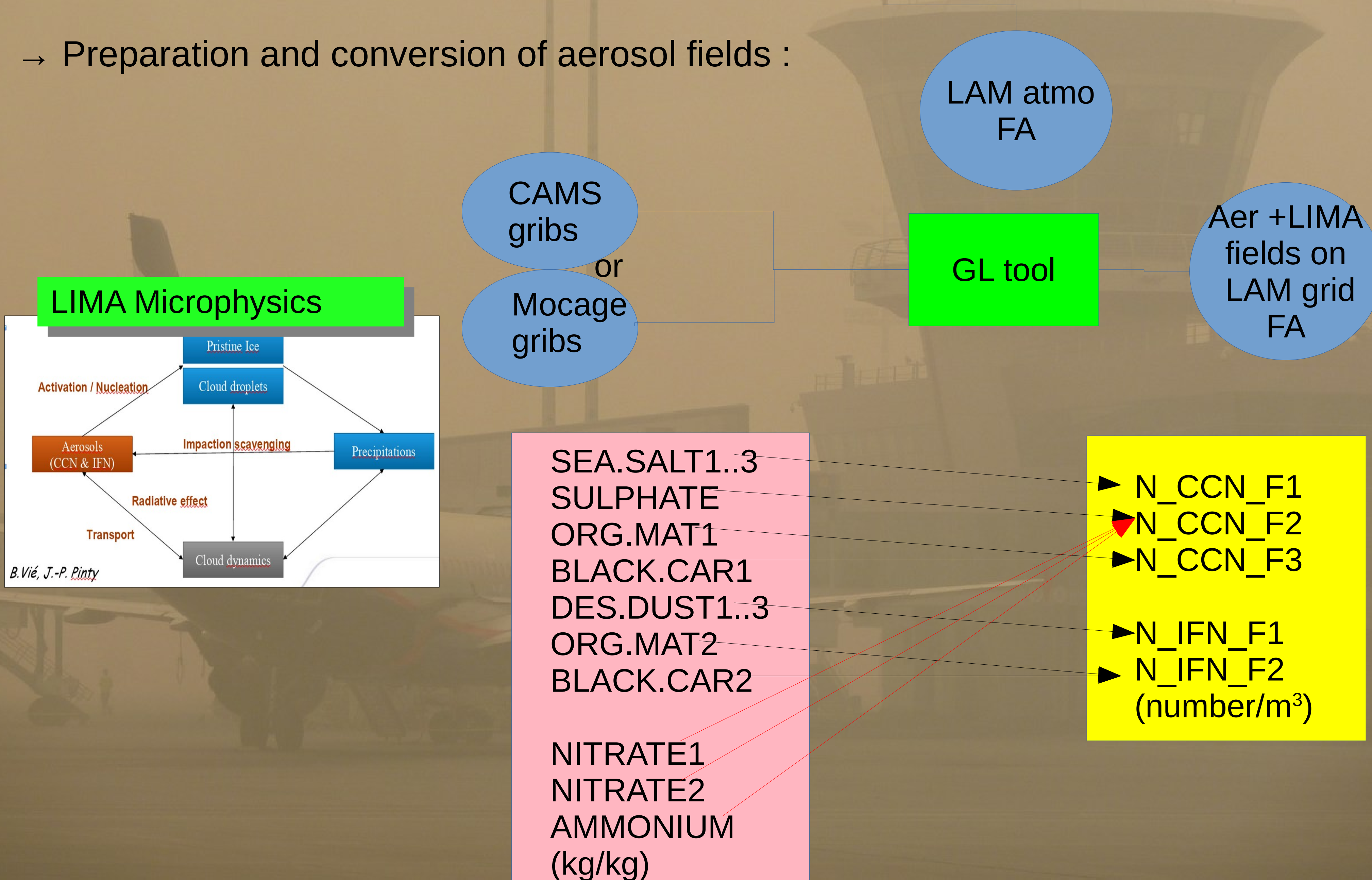
SAFNWC
Cloud type
(Satellite)



Aerosol MMRs for cloud microphysics parametrizations

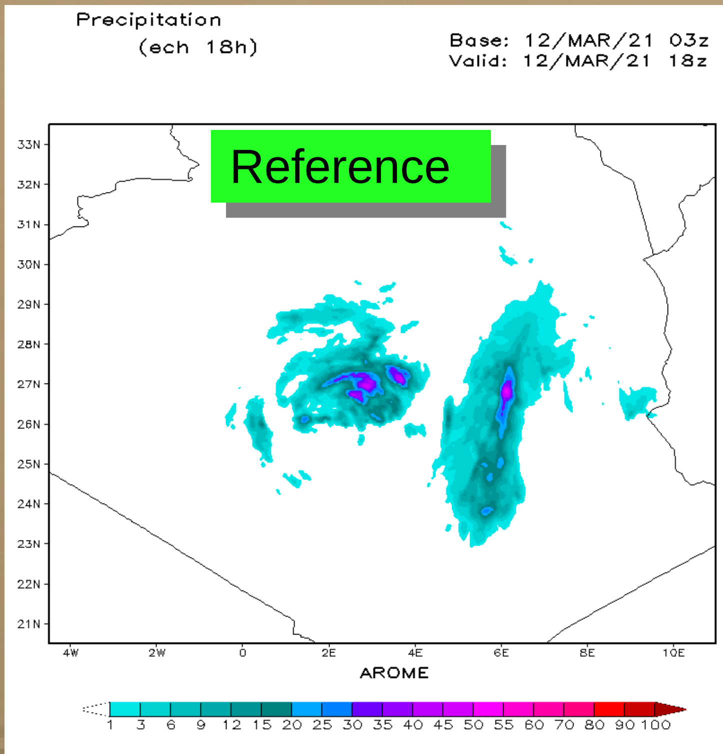
Links between aerosols and 2-moment microphysics

→ Preparation and conversion of aerosol fields :

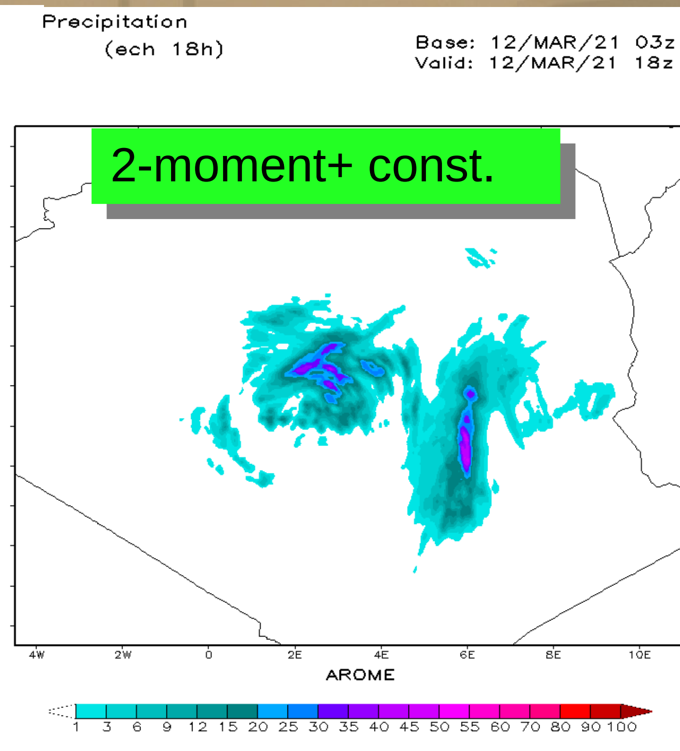


A convective case example (2021-03-12)

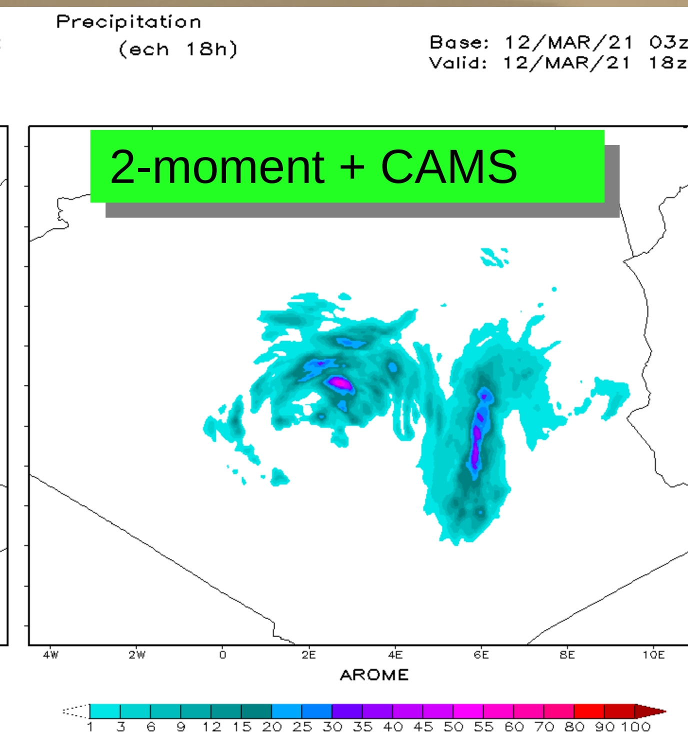
→ Test on AROME-Algeria domain (M. Mokhtari) :



(1-moment microphysics)

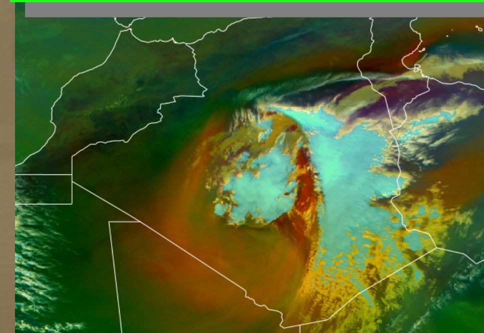


(LIMA with aero constant initialisation)

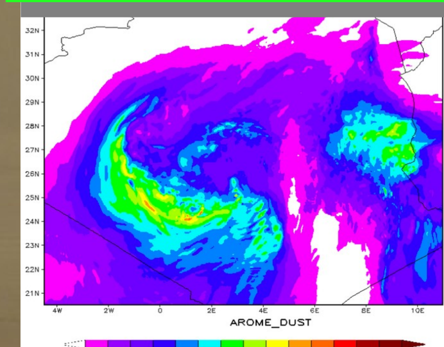


(LIMA with CAMS and AROME-Dust aero)

Satellite Observation



AROME-Dust AOD

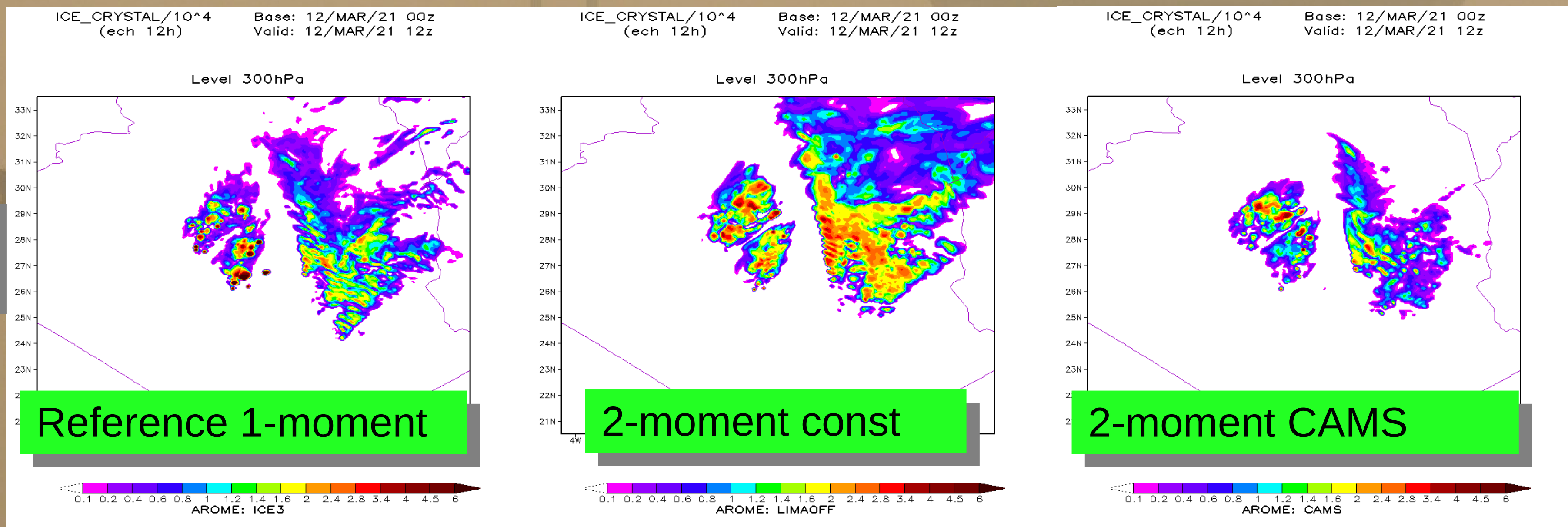


→ more light rain with LIMA
→ modified maxima
→ to be evaluated on longer periods

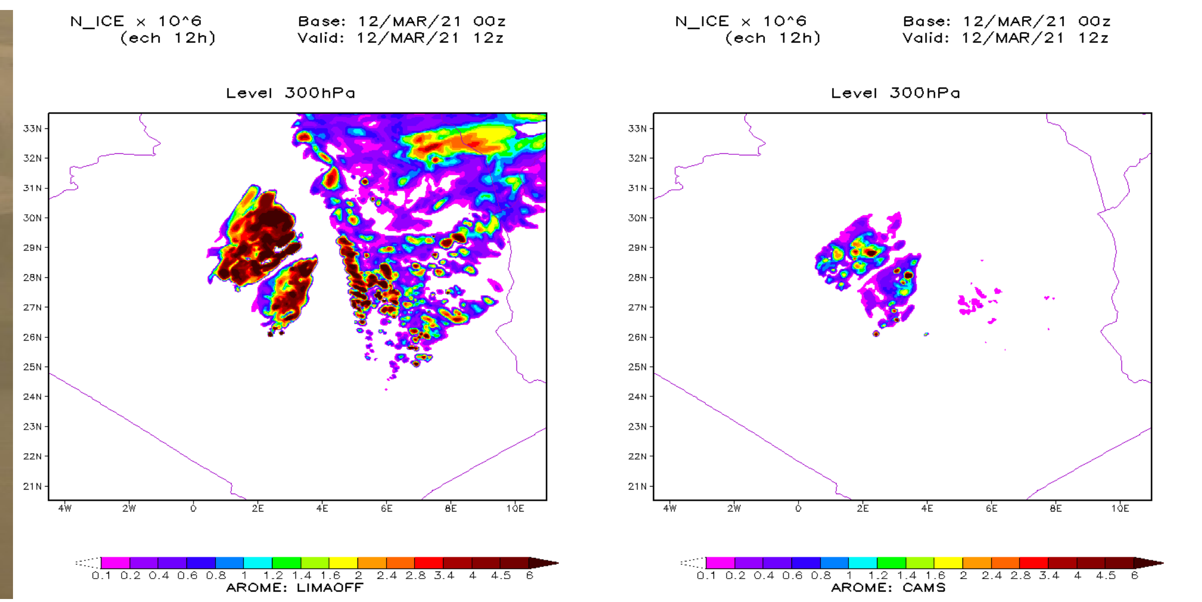
A convective case example (2021-03-12)

→ Differences in ice_crystals mass and number concentration:

Ice (kg/m^3)



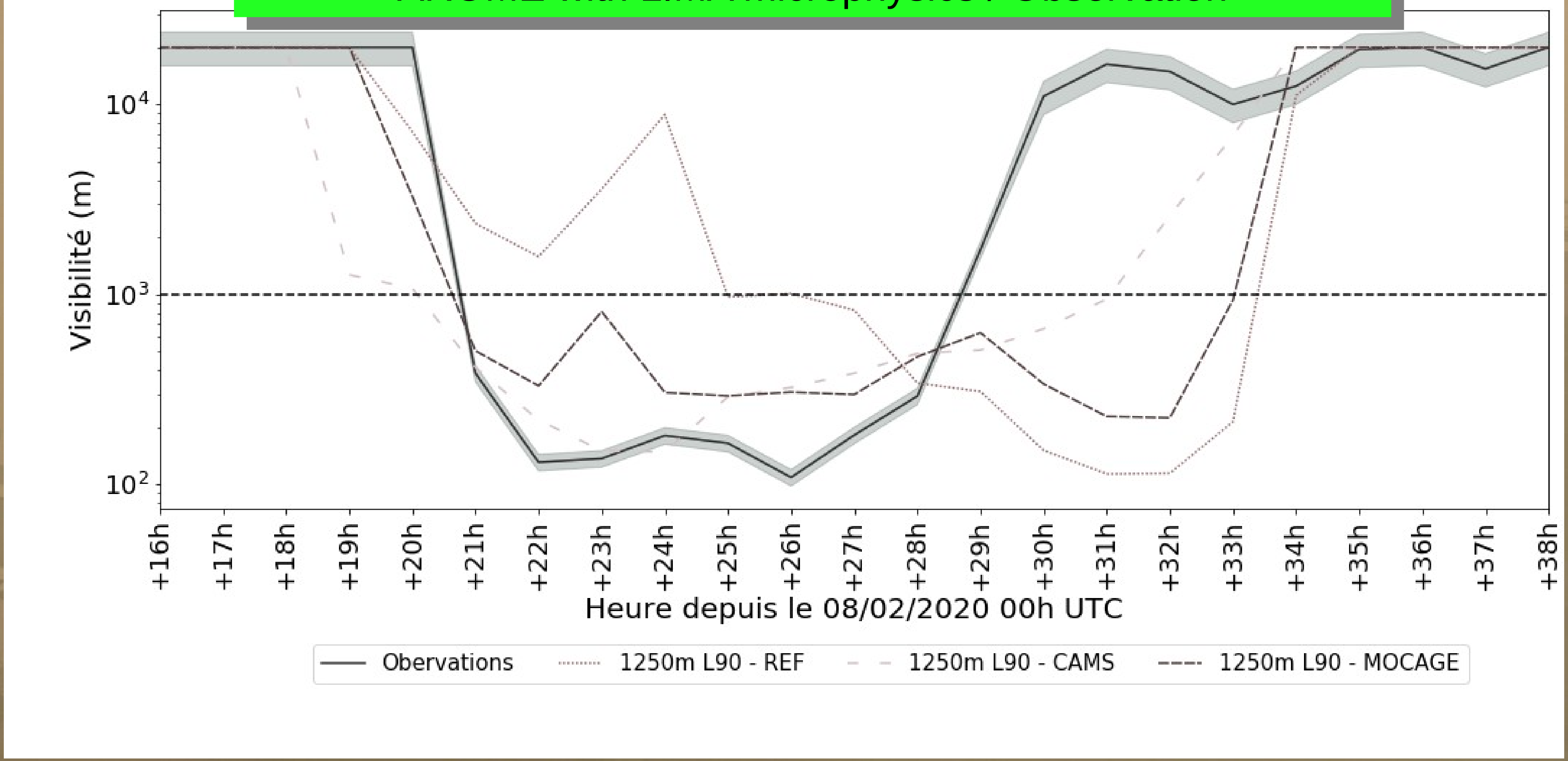
NIce ($/m^3$)



A fog case example (2020-02-08)

Tests on AROME-SOFOG1250 domain (S. Antoine) in the SO of France :

Temporal evolution of visibility forecasts at SOFOG supersite
AROME with LIMA microphysics / Observation



→ Improvements in the timing of the fog event

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Preliminary conclusions

Cloud, precipitation and fog evolution are sensitive to the atmospheric aerosol via cloud microphysics parametrizations (both liquid and ice phase)

Cloud droplet number concentration depends on aerosol concentration and influences both precipitation and, via cloud particle size, radiation transfer in clouds.

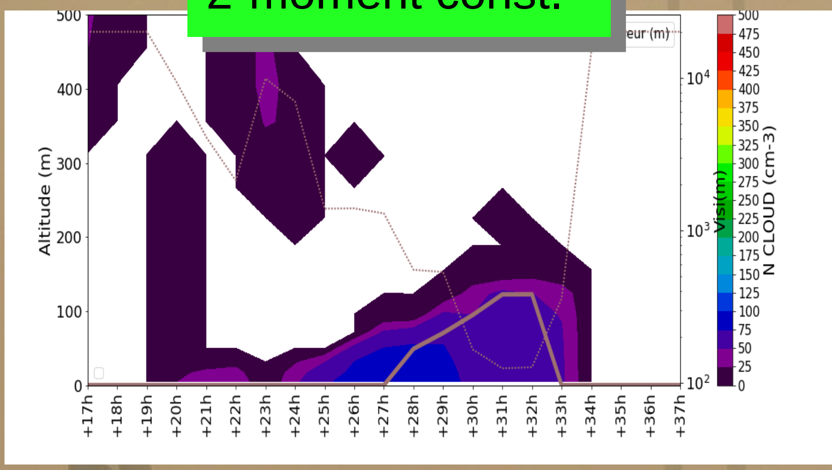
In clear-sky cases, the global SW radiation at the surface may reduce tens of W/m^2 due to direct radiation impact of aerosol

THANK YOU – DISCUSSION, QUESTIONS!

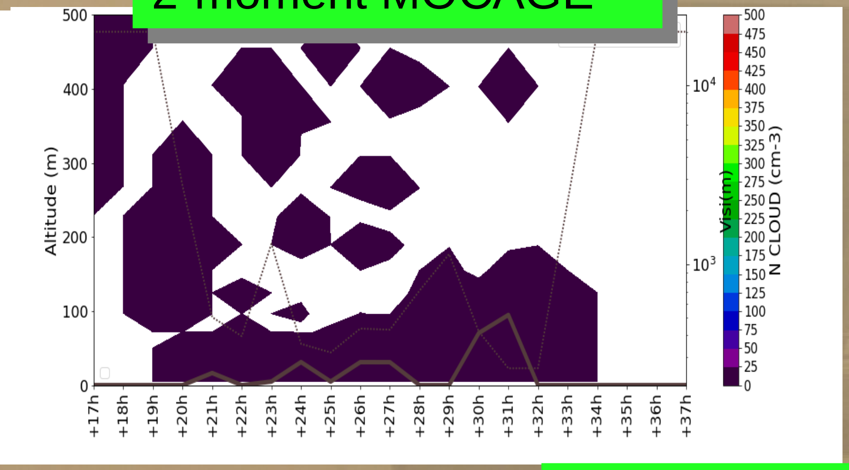
Saharan dust on melting snow on Helsinki sea ice 25.2.2021. Photo: Laura Rontu

A fog case example (2020-02-08):
Cloud droplet number concentration

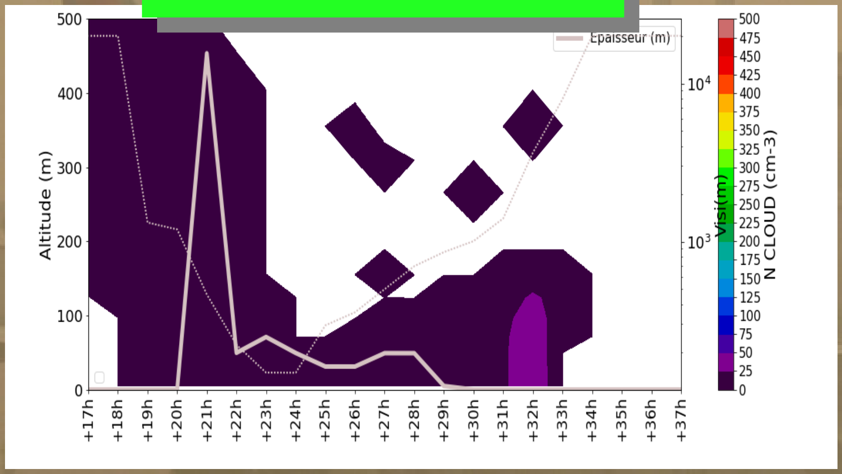
2-moment const.



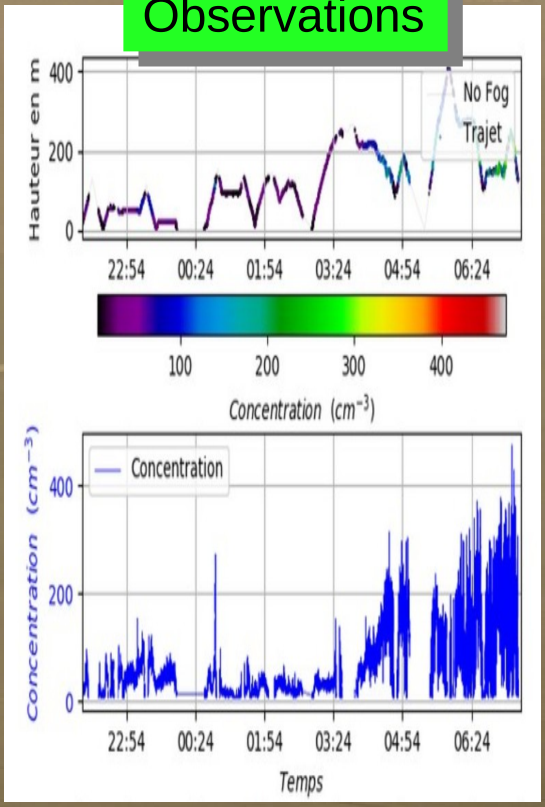
2-moment MOCAGE



2-moment CAMS



Observations



→ More sensibility than in the convective rainfall case
→ To be tested on longer periods

CAMS climatological or real-time 2D/3D mass mixing ratio of 11 aerosol categories

```
!SS1,SS2,SS3,DD1,DD2,DD3,OM1,OM2,BC1,SU
!CLSUF(1)='AEROMMR.SS1   ' Sea salt (RH, wavelength) size bin 1
!CLSUF(2)='AEROMMR.SS2   '  (hydrophilic)            size bin 2
!CLSUF(3)='AEROMMR.SS3   '                           size bin 3
!CLSUF(4)='AEROMMR.DD1  ' Desert dust (two flavours, wavelength) size bin 1
!CLSUF(5)='AEROMMR.DD2  '  (hydrophobic)             size bin 2
!CLSUF(5)='AEROMMR.DD3  '                            size bin 3
!CLSUF(7)='AEROMMR.OM1  ' Organic matter hydrophilic (RH, wavelength)
!CLSUF(8)='AEROMMR.OM2  '                hydrophobic (wavelenght)
!CLSUF(9)= 'AEROMMR.BC1  ' Black Carbon hydrophilic (RH,wavelength)
!CLSUF(10)='AEROMMR.BC2 '               hydrophobic (wavelenght)
!CLSUF(11)='AEROMMR.SUL ' Tropospheric sulphates (RH, wavelenght)
                                        (hydrophilic)
```

based on C-IFS forecasts that include data assimilation

ALSO AVAILABLE:

SO2 precursor mixing ratio	aermr12
Volcanic ash aerosol mixing ratio	aermr13
Volcanic sulphate aerosol mixing ratio	aermr14
Volcanic SO2 precursor mixing ratio	aermr15

ASW20

Aerosol optical properties prescribed by ECMWF

Assumptions for 11 aerosol species:

- Spherical particles
- Log-normal size number distribution
- Prescribed refractive index and density of particles, depending on humidity

Mie scattering calculations →

Inherent optical properties of 11 aerosol types for 14+16 RRTM wavelengths

ME mass extinction coefficient - AOD = ME * MMR
SSA single scattering albedo – scattering/absorption
ASY asymmetry factor – prevailing direction of scattering

Bozzo, A., Remy, S.,Benedetti, A., Flemming, J., Bechtold, P., Rodwell, M. J.,Morcrette, J.-J.: Implementation of a CAMS-based aerosol climatology in the IFS, ECMWF Technical Memorandum, 801 2017

Aerosol optics

Aerosol IOP* data available

SW [nm]	LW [µm]
3846 – 12195	28.57 – 1000.00
3077 - 3846	20.00 - 28.57
2500 - 3077	15.87 - 20.00
2151 - 2500	14.29 - 15.87
1942 - 2151	12.20 - 14.29
1626 - 1942	10.20 - 12.20
1299 - 1626	9.26 - 10.20
1242 - 1299	8.47 - 9.26
778 - 1242	7.19 - 8.47
625 - 778	6.76 - 7.19
442 - 625	5.56 - 6.76
345 - 442	4.81 - 5.56
263 - 345	4.44 - 4.81
200 - 263	4.20 - 4.44
	3.85 - 4.20
	3.08 - 3.85

Default radiation parametrizations in HARMONIE-AROME:

Solar radiation flux at 6 spectral intervals of IFS scheme
0.185 – 0.25 – 0.44 – 0.69 – 1.19 – 2.38 – 4.00 µm
0 % 11 % 38 % 35 % 15 % 0.4 %

Terrestrial radiation flux is calculated at 16 spectral intervals of the RRTM (IFS) scheme
- but presently only AOD of 6 LW bands is used

Broadband (1 SW + 1 LW band) IOP's needed for ACRANEB, HLRADIA

* IOP = inherent optical properties:
mass extinction, asymmetry, single-scattering albedo