

# ACCORD-AROME

## aerosol studies

Daniel Martín Pérez   Yann Seity   Laura Rontu  
AEMET Spain   Meteo France   FMI Finland

27 September to 1 October 2021

The 43rd European Working Group on Limited-Area Modelling (EWGLAM) /  
28th Short Range NWP (SRNWP) EUMETNET meeting

Murcia 19 Feb 2021 towards south. Photo Jakob Lödjqvist

# Contents

Introduction: From Sahara to Helsinki

Near-real-time aerosols for ACCORD AROME

HARMONIE-AROME with ICE3 microphysics

MF-AROME with LIMA microphysics

Outlook and conclusions

# From Sahara to Helsinki

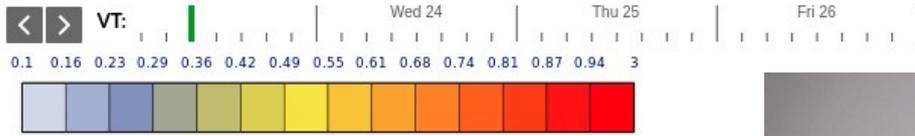
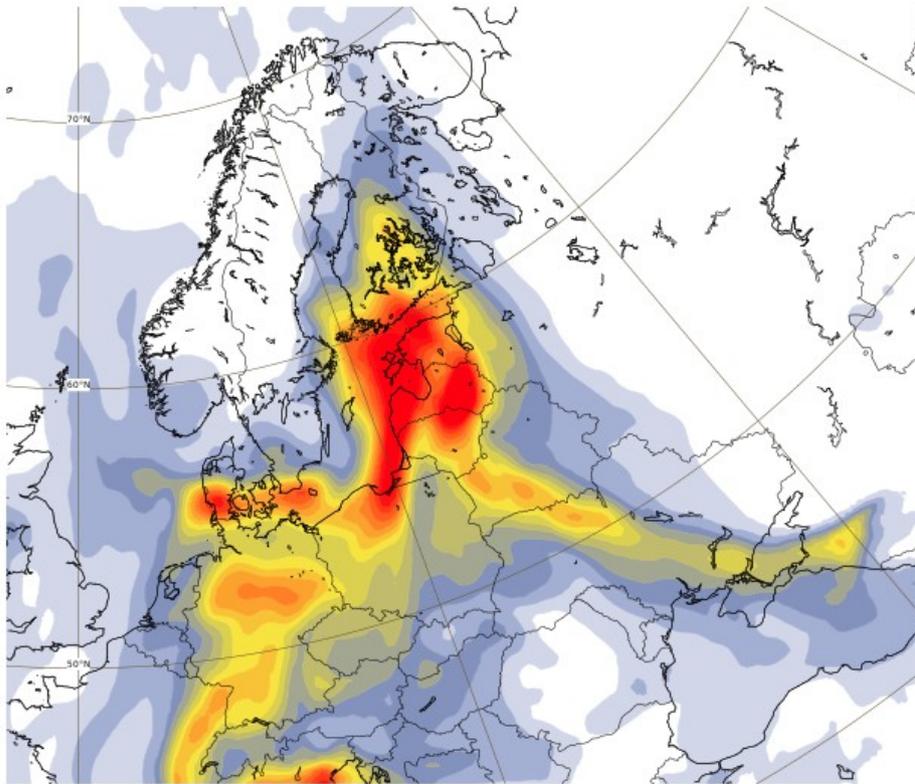


20210225 15UTC melting snow on sea ice, Helsinki

# 20210223 09UTC

Base time: Tue 23 ... Area: North East E... Aerosol type: Total ...

Aerosol optical depth at 550 nm (provided by CAMS, the Copernicus Atmosphere Monitoring Serv...)  
Tuesday 23 Feb, 00 UTC T+9 Valid: Tuesday 23 Feb, 09 UTC



Aerosol optical depth at 550 nm (provided by CAMS, the Copernicus Atmosphere Monitoring Serv...)  
CAMS aerosol forecasts

Precipitation Type, , at 09Z Tue 23 Feb  
MEPS mbr0: 2021022306+3h0min, cy40h1.1, 2.5 km



20°E

30°E 50°N



# Aerosol MMRs for cloud microphysics parametrizations



Helsingin Sanomat maanantaina 1.3.2021 ■ 9  
KOTIMAA

## Saharan hiekkaa pyydettiin lähettämään tutkimukseen

Sää | Hiekkaa tarvitaan kymmeniä grammoja jäädytyskokeita varten.

"Sitteen nähdään, että kun tynyistä hiukasta pisteään sinne, missä lämmössä ja kosteudessa syntyy jääkkeitä." Jos ne ovat tehokkaita jäädyttäjiä, jäät muodostuu Laakson mukaan jo silloin, kun suhteellinen ilmakeitos on juuri ja juuri sellainen, että jäätä voisi ylipäänsä muodostua. Laakson mukaan tällä hetkellä ymmärretään yllättävänkin huonosti sitä, millaisia hiukkasia 5-15 kilometrin korkeuksissa on ja mikä niistä ovat tehokkaita ytimiä jääkkeitä.

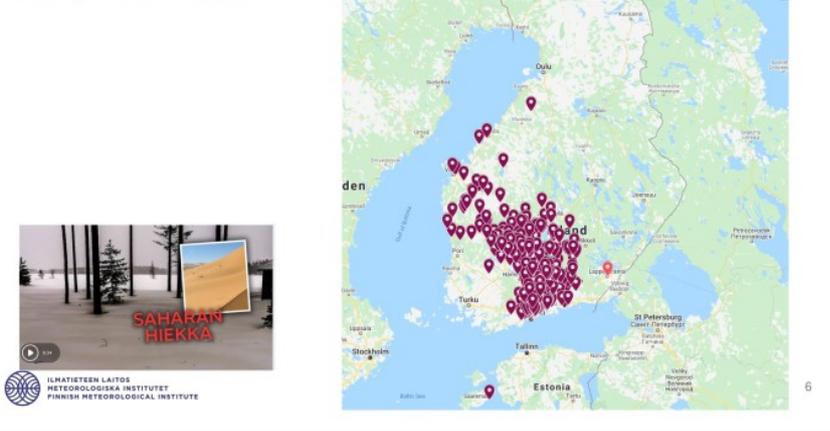
SAHARASTA tulee tuulen mukana harvoin hiekkaa Suomeen, mutta nyt ajoitus oli erinomainen. Ilmatieteen laitoksella on Laakson mukaan syksyllä alkamassa tutkimusprojekti, jossa juuri tämänkaltaisia asioita tutkitaan. Toinen projekti on pariaikaa käynnissä. "Tähän sattui nyt vähän tällainen onnenkantamoinen, että juuri sellaista tavaraa tuli tänne, mistä olemme kiinnostuneet." Vaikka hiekkaa ei saataisi kerättyä tarpeeksi jäädytyskokeita varten, saatuja näytteitä tutkitaan esimerkiksi mikroskoopin ja muilla menetelmillä. Niistä joitakin tuloksia saadaan julki ehkä jo tulevina viikkoina. "Nämä jäädytyskokeet vievät pidempään, mutta jos tavaraa tulee tarpeeksi, joitakin tuloksia meillä on parin kuukauden ajankänteellä. Jos tulokset ovat kelvollisia, ne julkaistaan jossain vaiheessa tieteellisessä kirjallisuudessa. Siihen mene suurin piirtein vuosi", Laakson sanoo. Keräysohjeesta kertoi aiemmin Aamulehti.

io Pellinen STT

KIN Jonkin verran näyttää an hiekasta saapu postitieteen laitokselle alkukolla. Hiekkaa tarvitaan ääsiä yläpölyä eli cirrus-sittilevää tutkimuksiä ertto laitoksen tieteilijä Ari Laaksonen. si lauantaina Twitteriä suodattamaan luasta viime tistain ja paikkeilla tulla tettäminen sitä laidenottoja oli sunvään mennessä nen. Posti alkaa a vasta viikon-  
...otetaan yli seitsemän 2 desilitraa sulata ja suodatta vateko ne tehokkaasti näiden yläpölyjen jääkkeitä ympärilleen. Koska jos muodostavat, sillä on merkitystä siihen, millaisia niiden pölyjen ilmastolliset ominaisuudet ovat maapallolle saapuvan auringonvalon kannalta", Laaksonen kertoo.

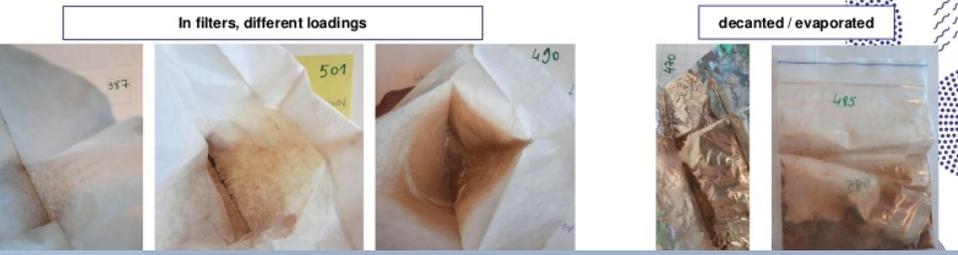
Ohje 1: Saharan hiekanäyte suodattamalla  
Ohje 2: Saharan hiekanäyte haihduttamalla

## 525 citizen samples of Saharan dust deposition



## Samples

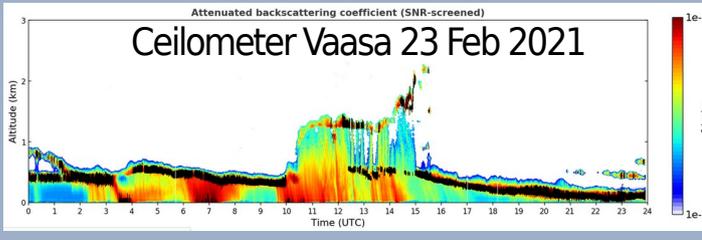
- Dusty snow samples in freezer
- Dust particles on snow:
  - filtered
  - evaporated
  - decanted



Courtesy of outi.meinander@fmi.fi

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.

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.



# Contents

Introduction: From Sahara to Helsinki

Near-real-time aerosols for ACCORD AROME

HARMONIE-AROME with ICE3 microphysics

MF-AROME with LIMA microphysics

Outlook and conclusions



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 forecasts

### Filters

Show All

### Family

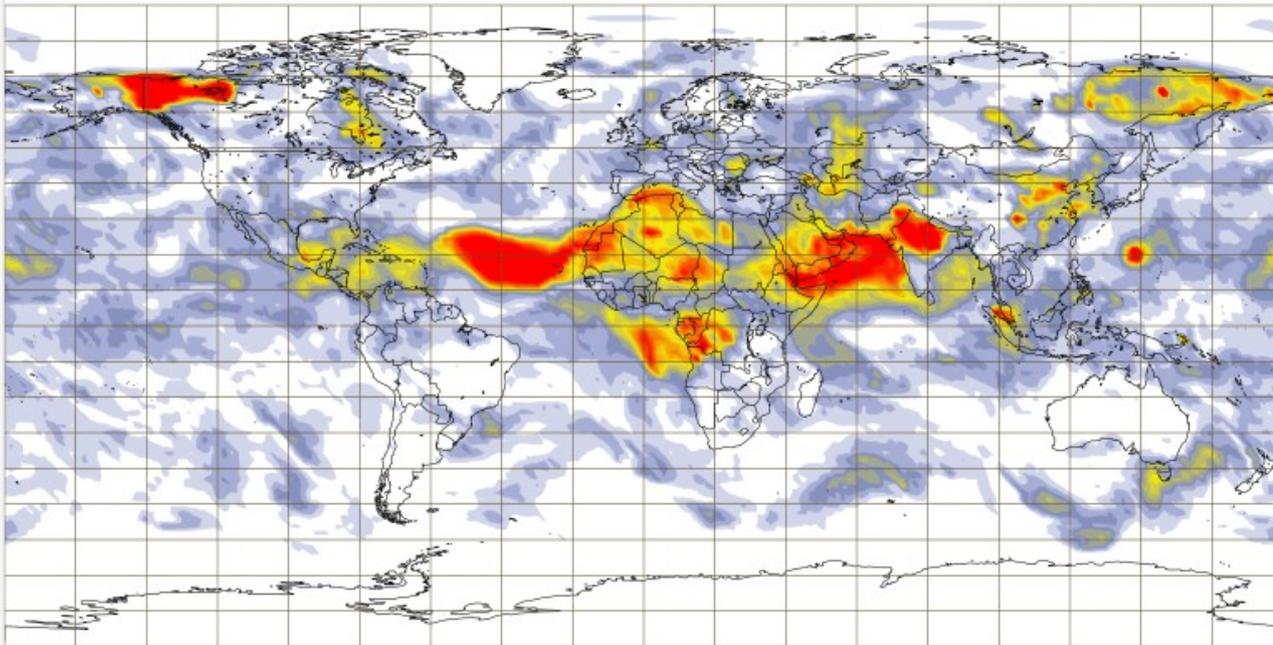
Aerosols (2)

[show 4 more](#)

Base time Area Aerosol type

Filter results

**Aerosol optical depth at 550 nm (provided by CAMS, the Copernicus Atmosphere Monitoring Service)**  
Sunday 8 Jul, 00 UTC T+3 Valid: Sunday 8 Jul, 03 UTC



# 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

Climatology

resolution 2.5 deg

clim  
developing

2D integrated

MMR

(x,y,z) for 11 species

IOPs

ME, SSA, ASY  
(14+16  $\lambda$ , RH, 11 species)

Radiation (and clouds)

Made in climate generation

Near-real-time

resolution 0.5 deg

n.r.t.  
developing

3D and 2D integrated

MMR

(x,y,z) for 14 species

IOPs

ME, SSA, ASY  
(14+16  $\lambda$ , RH, 14 species)

Radiation (and clouds)

Imported via boundaries

RELOCATING DUCKS

# 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

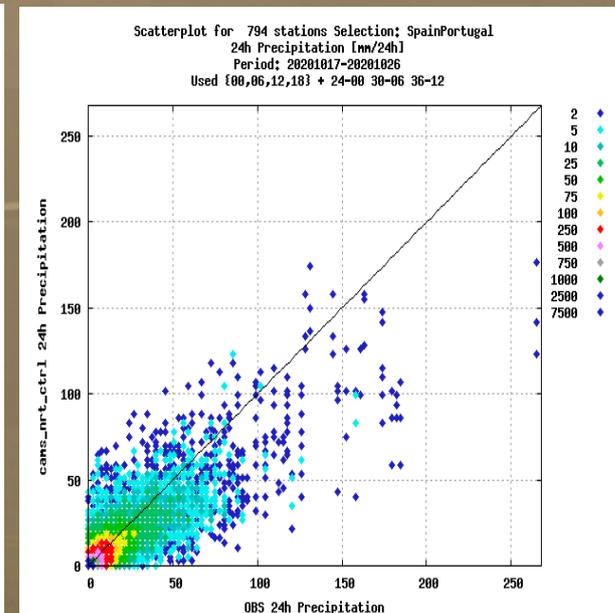
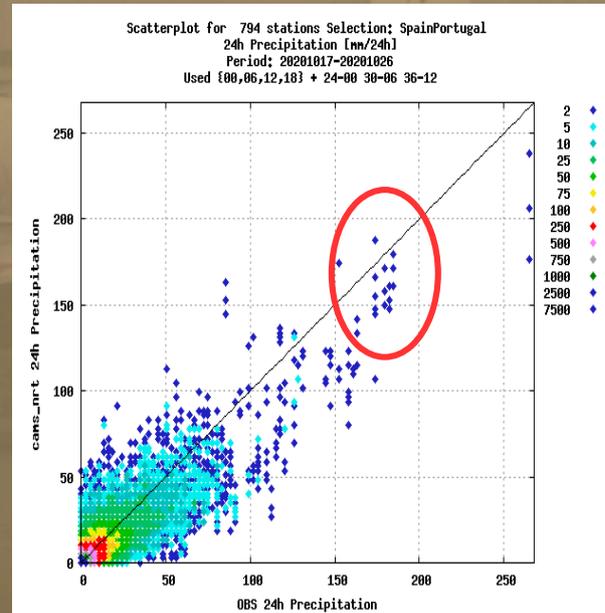
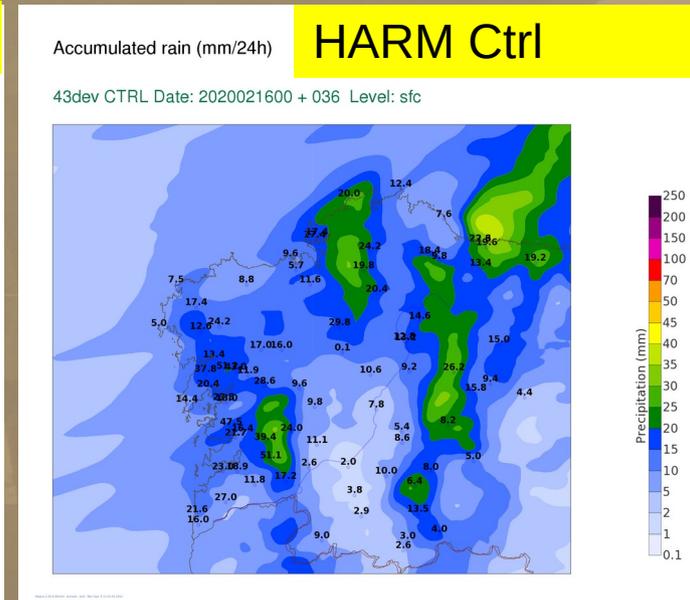
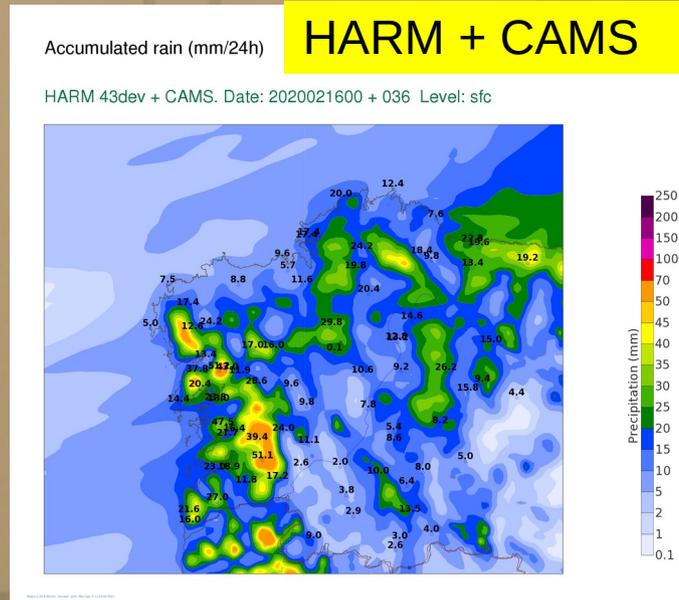
Impact on Precipitation.

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

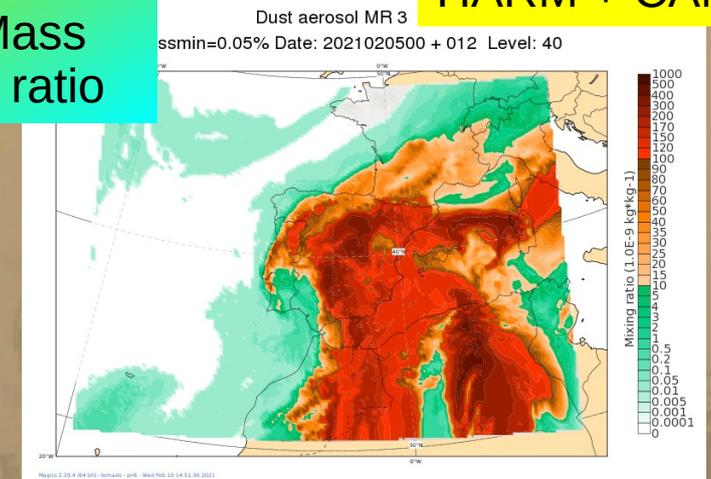
## Impact on Radiation

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

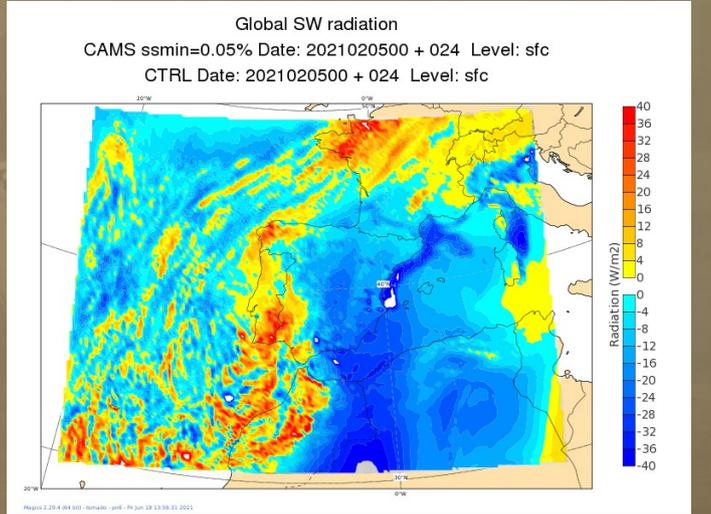
Case:20210205

## HARM + CAMS

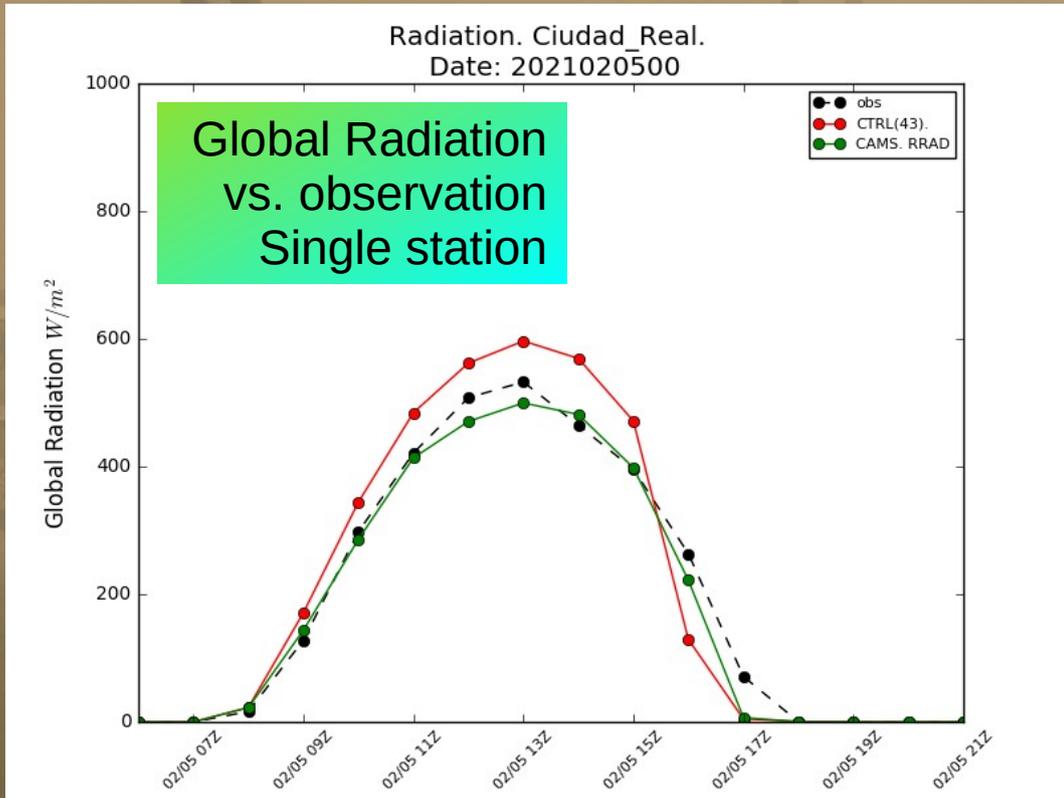
Dust Mass mixing ratio



## Global Radiation



(HARM + CAMS) – (HARM ctrl)



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

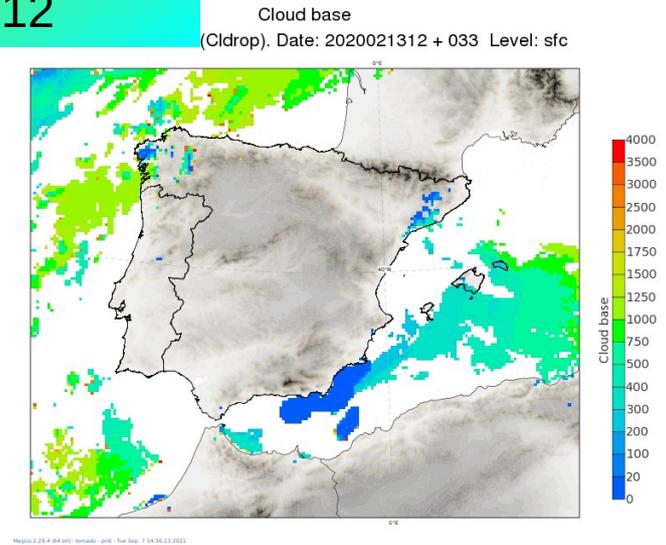
## Impact on fog

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

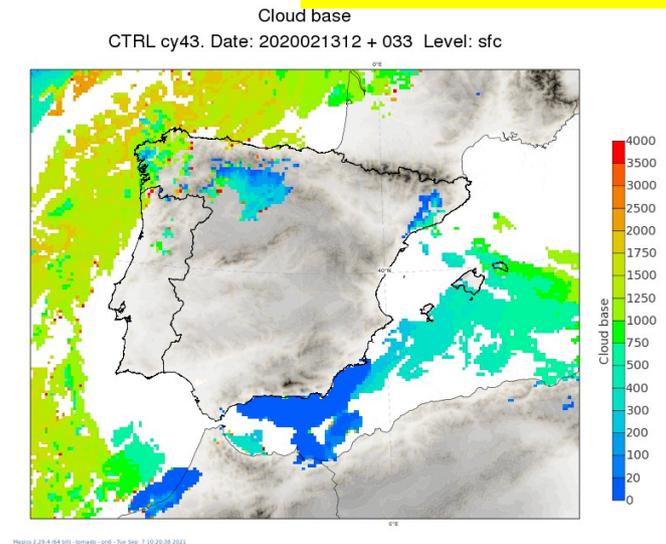
It also reduces the anomalous fogs that sometimes appear over sea. (Although this problem might be related with a wrong cloud droplet distribution in these cases)

HARM + CAMS

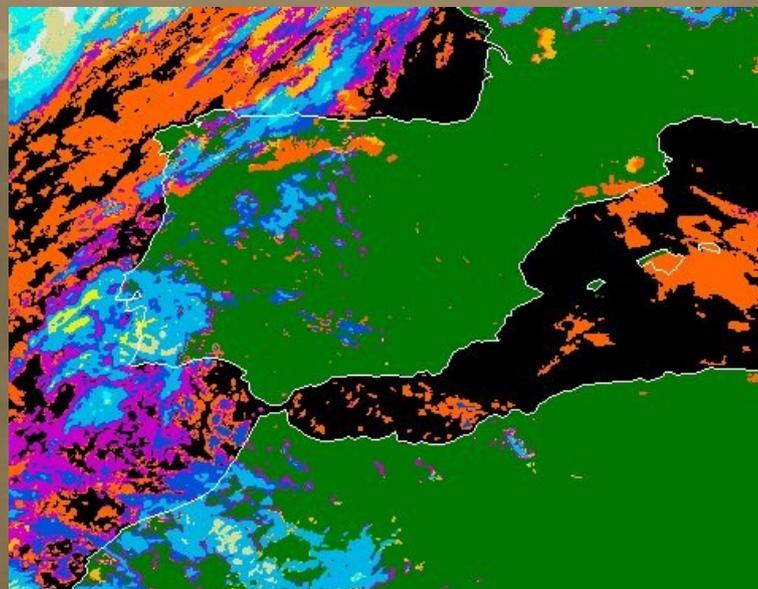
Cloud base height  
2020021312



HARM Ctrl



SAFNWC  
Cloud type  
(Satellite)



# Aerosol MMRs for cloud microphysics parametrizations



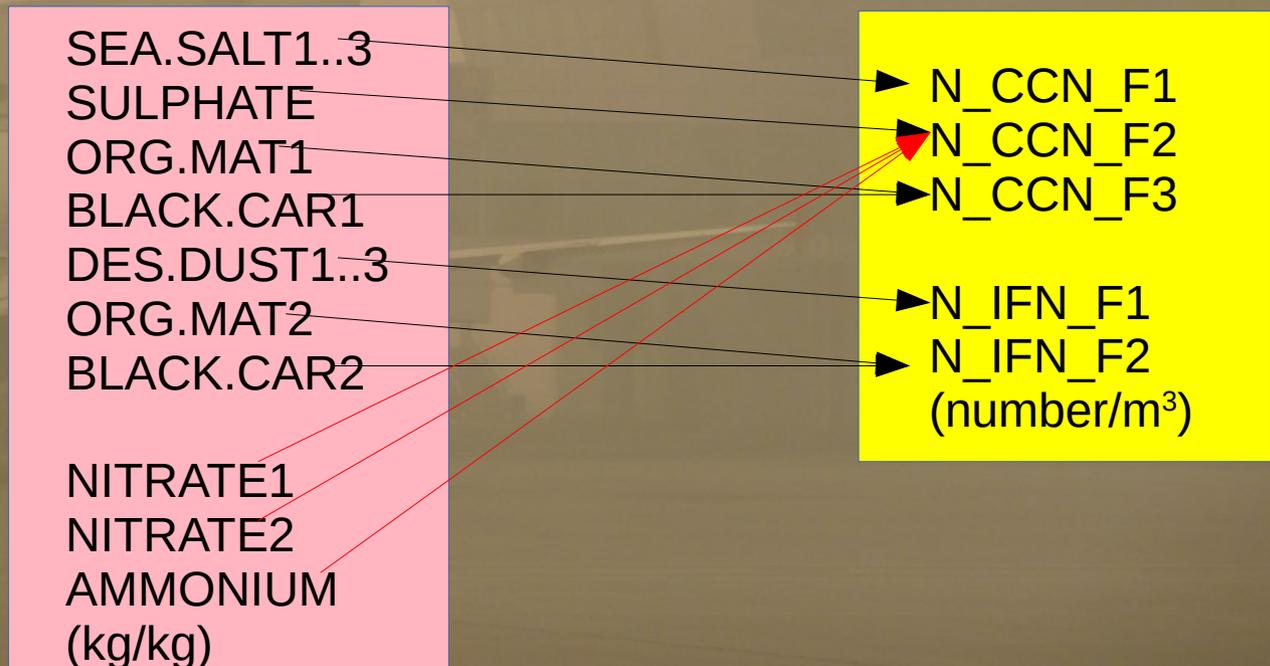
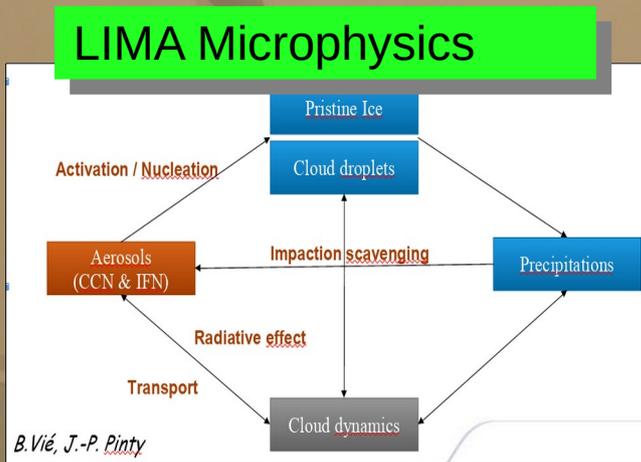
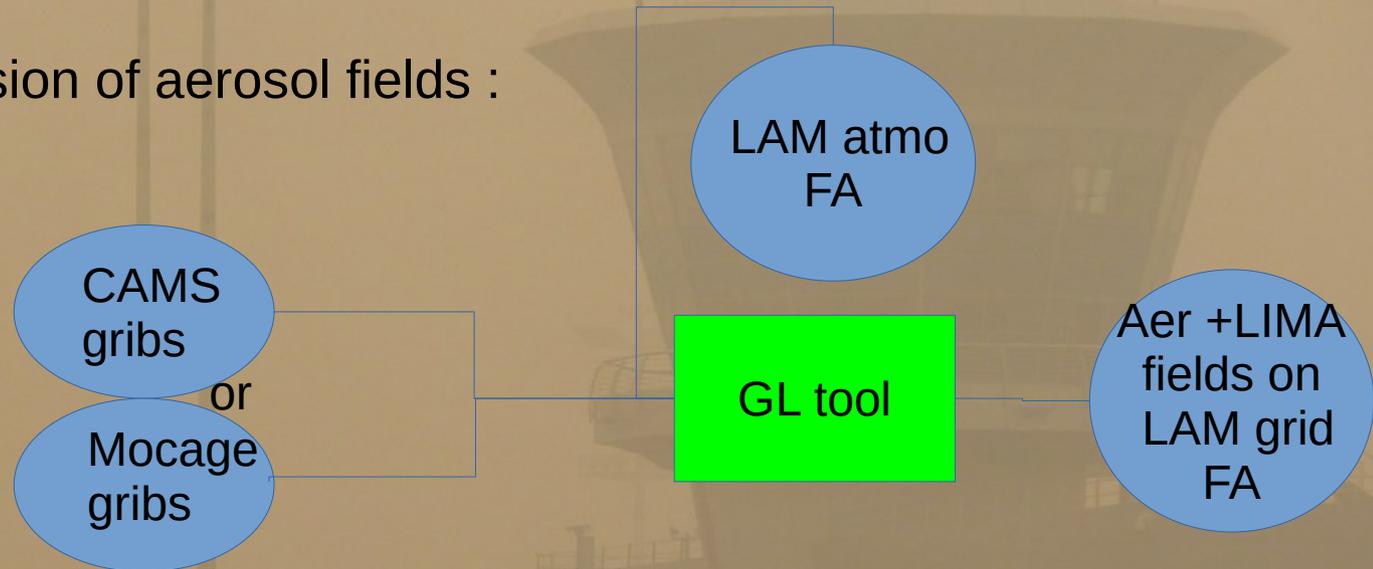
HARMONIE-AROME  
with ICE3 microphysics



Meteo France-AROME  
with LIMA microphysics

# 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) :

Precipitation  
(ech 18h)

Base: 12/MAR/21 03z  
Valid: 12/MAR/21 18z

Precipitation  
(ech 18h)

Base: 12/MAR/21 03z  
Valid: 12/MAR/21 18z

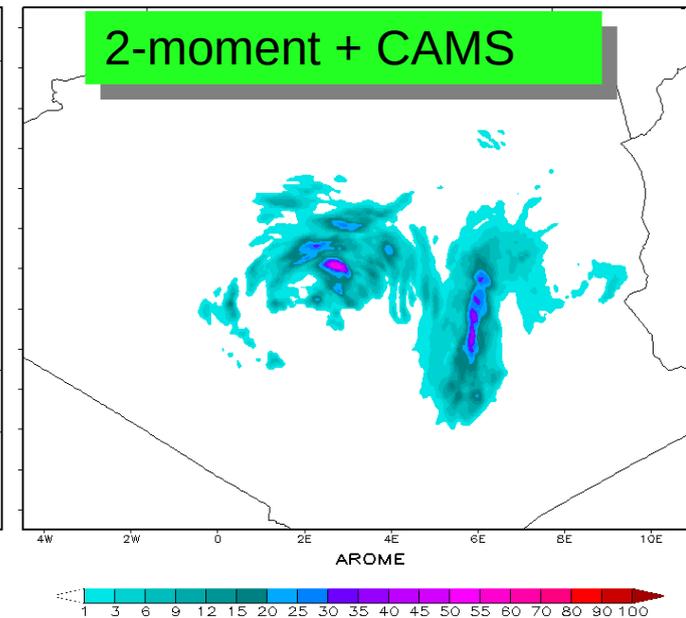
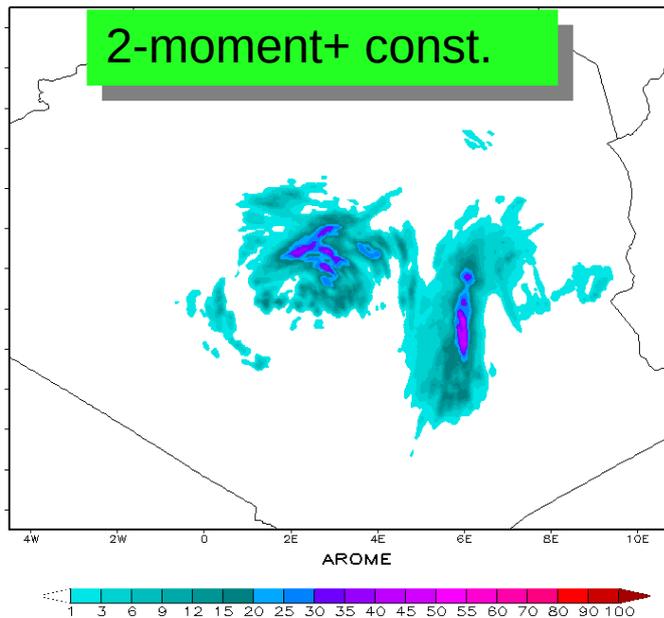
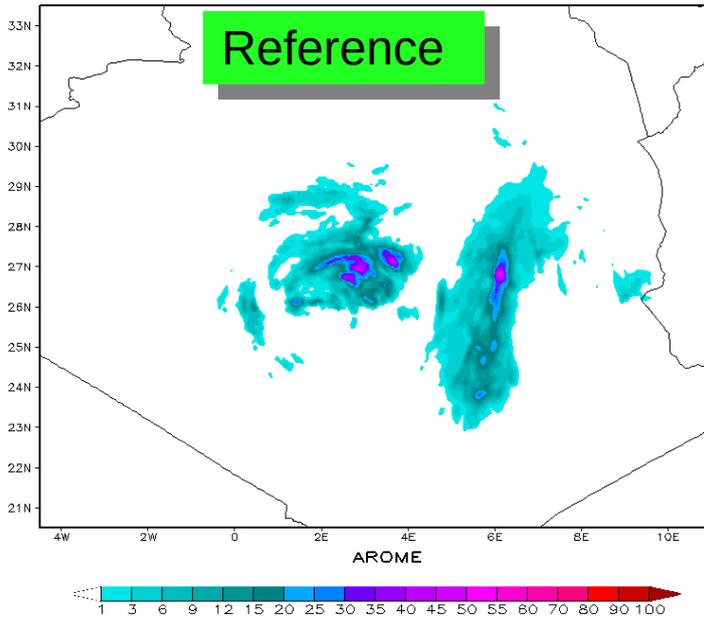
Precipitation  
(ech 18h)

Base: 12/MAR/21 03z  
Valid: 12/MAR/21 18z

Reference

2-moment+ const.

2-moment + CAMS



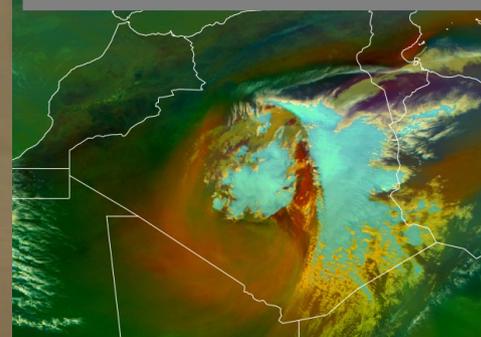
(1-moment microphysics)

(LIMA with aero constant initialisation)

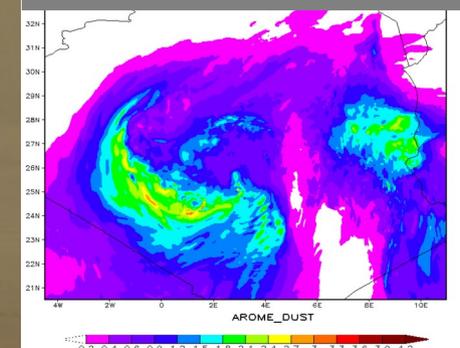
(LIMA with CAMS and AROME-Dust aero)

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

Satellite Observation

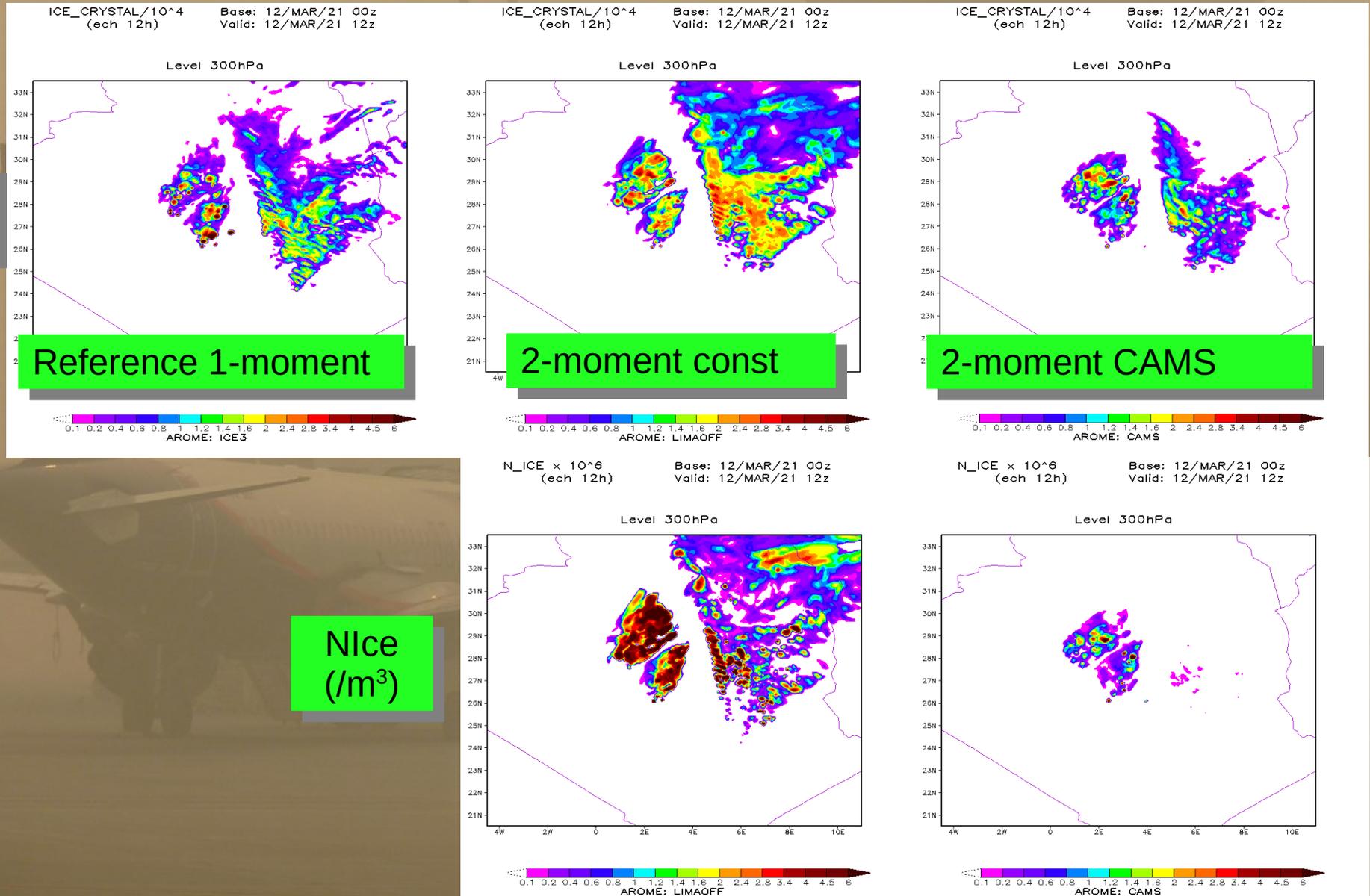


AROME-Dust AOD



# A convective case example ( 2021-03-12)

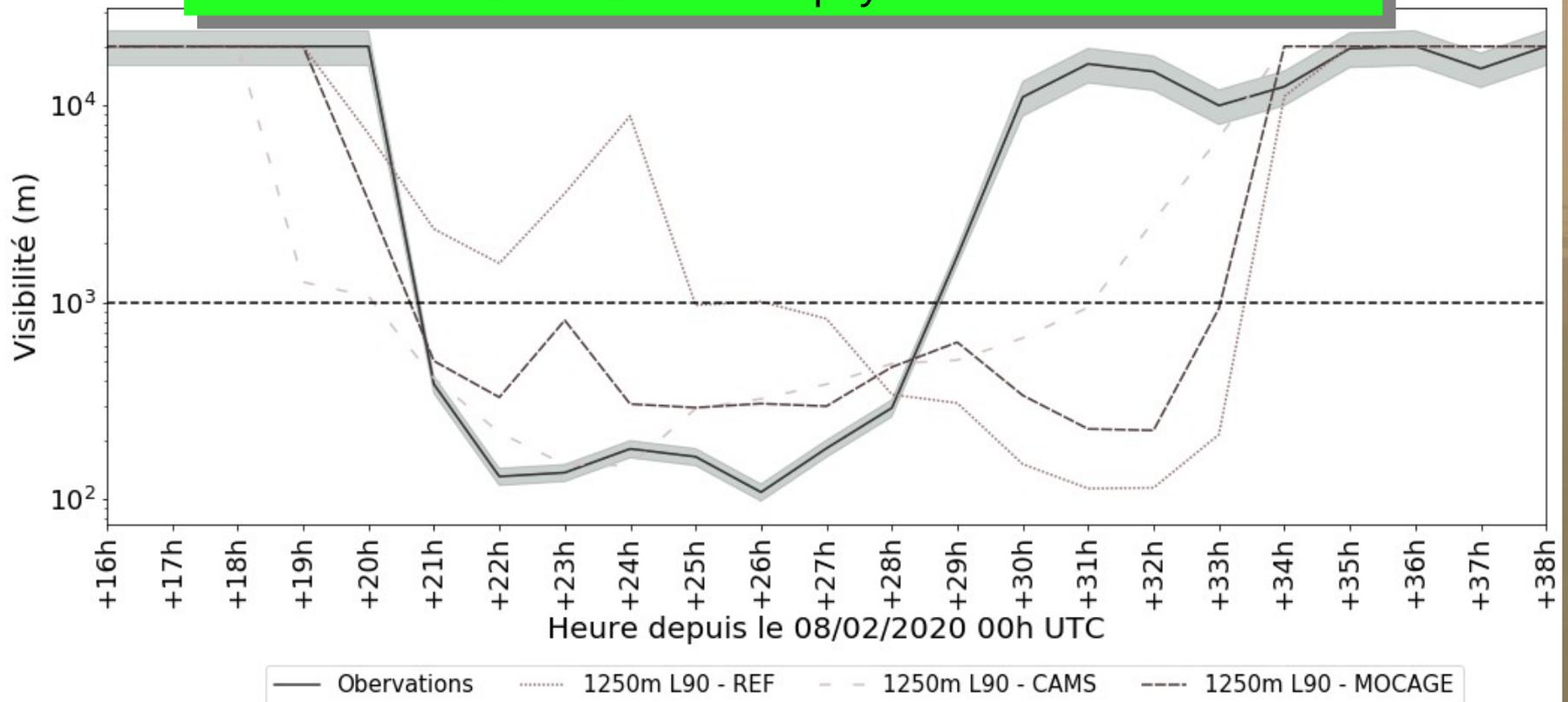
→ Differences in ice\_crystals mass and number concentration:



# 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

# Contents

Introduction: From Sahara to Helsinki

Near-real-time aerosols for ACCORD AROME

HARMONIE-AROME with ICE3 microphysics

MF-AROME with LIMA microphysics

Outlook and conclusions

# 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  $\text{W/m}^2$  due to direct radiation impact of aerosol

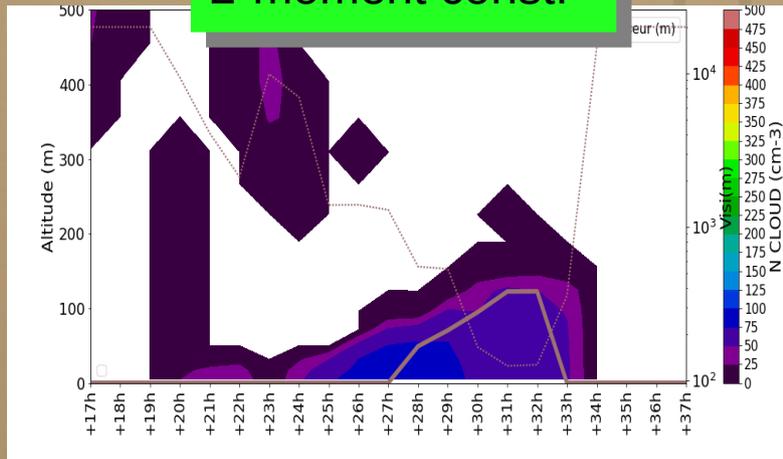
A close-up photograph of melting snow on Helsinki sea ice. The snow is white and textured, with numerous small, irregular brown spots scattered across it, representing Saharan dust. The background is a soft, out-of-focus greyish-blue.

**THANK YOU - DISCUSSION, QUESTIONS!**

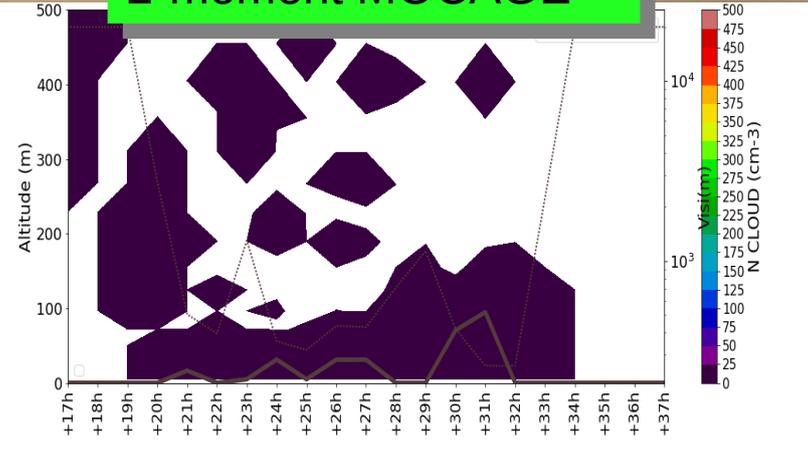
Saharan dust on melting snow on Helsinki sea ice 25.2.2021. Photo: Laura Rontu

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

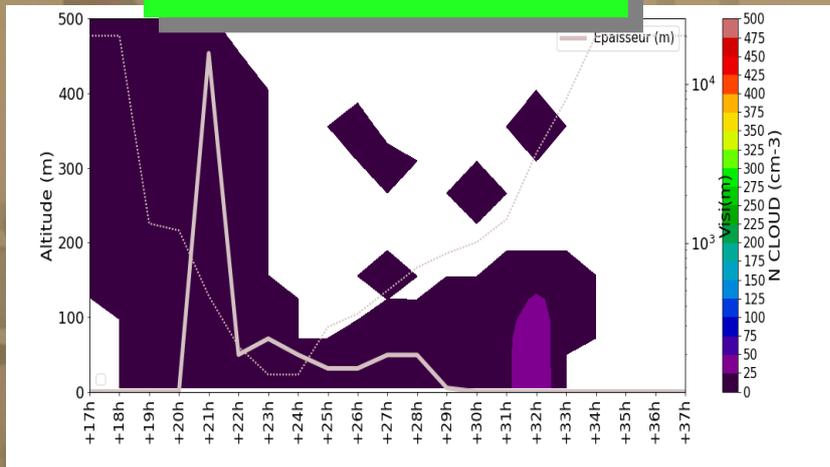
2-moment const.



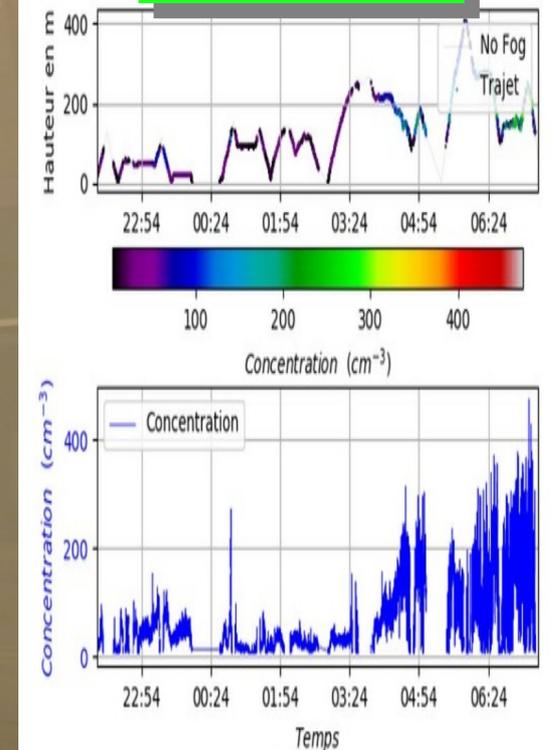
2-moment MOCAGE



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 (wavelength)
- !CLSUF(9)='AEROMMR.BC1 ' Black Carbon hydrophilic (RH,wavelength)
- !CLSUF(10)='AEROMMR.BC2 ' hydrophobic (wavelength)
- !CLSUF(11)='AEROMMR.SUL ' Tropospheric sulphates (RH, wavelength) (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

# 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

# Aerosol optics

Aerosol IOP\* data available

SW [nm]	LW [ $\mu\text{m}$ ]
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  $\mu\text{m}$   
 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