Dust and weather 3000 km apart - the case of February 2021 in Finland

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FMI Finland IMGW Poland AEMET Spain

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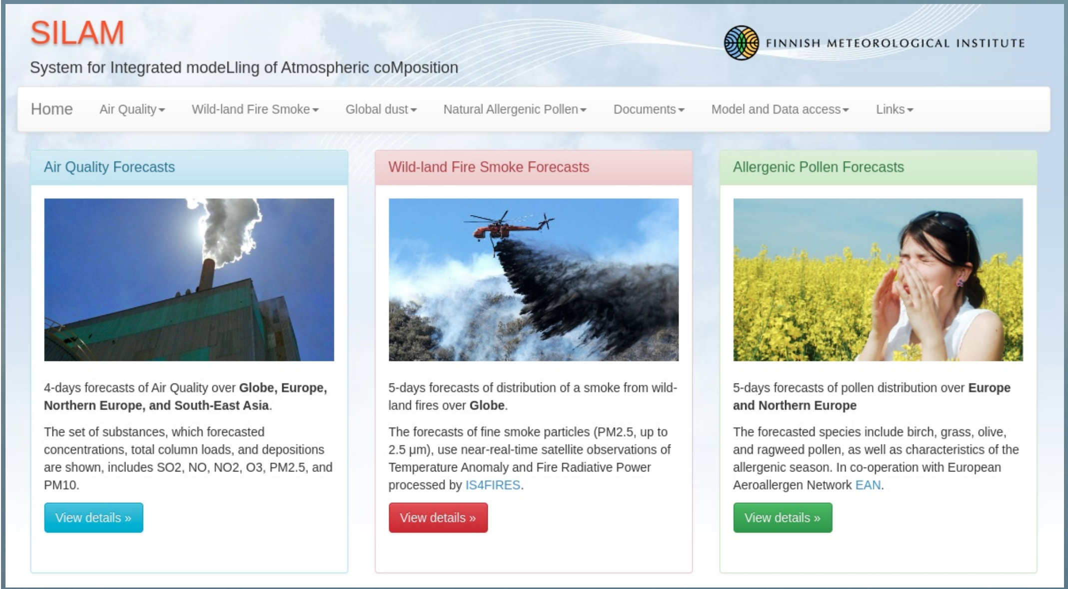
From the 1st of January 2021, 26 Euro-Mediterranean National Met Services have decided to enter into a larger partnership and create a single consortium: ACCORD, built on the ALADIN, LACE and HIRLAM consortia.

HARMONIE-AROME is a high-resolution limited area NWP system within ACCORD, applied operationally in the HIRLAM countries

In HARMONIE-AROME, near-real-time aerosol data from Copernicus Atmosphere Monitoring Service (CAMS) can be coupled to the weather model for application in radiation and cloud microphysics parametrizations.



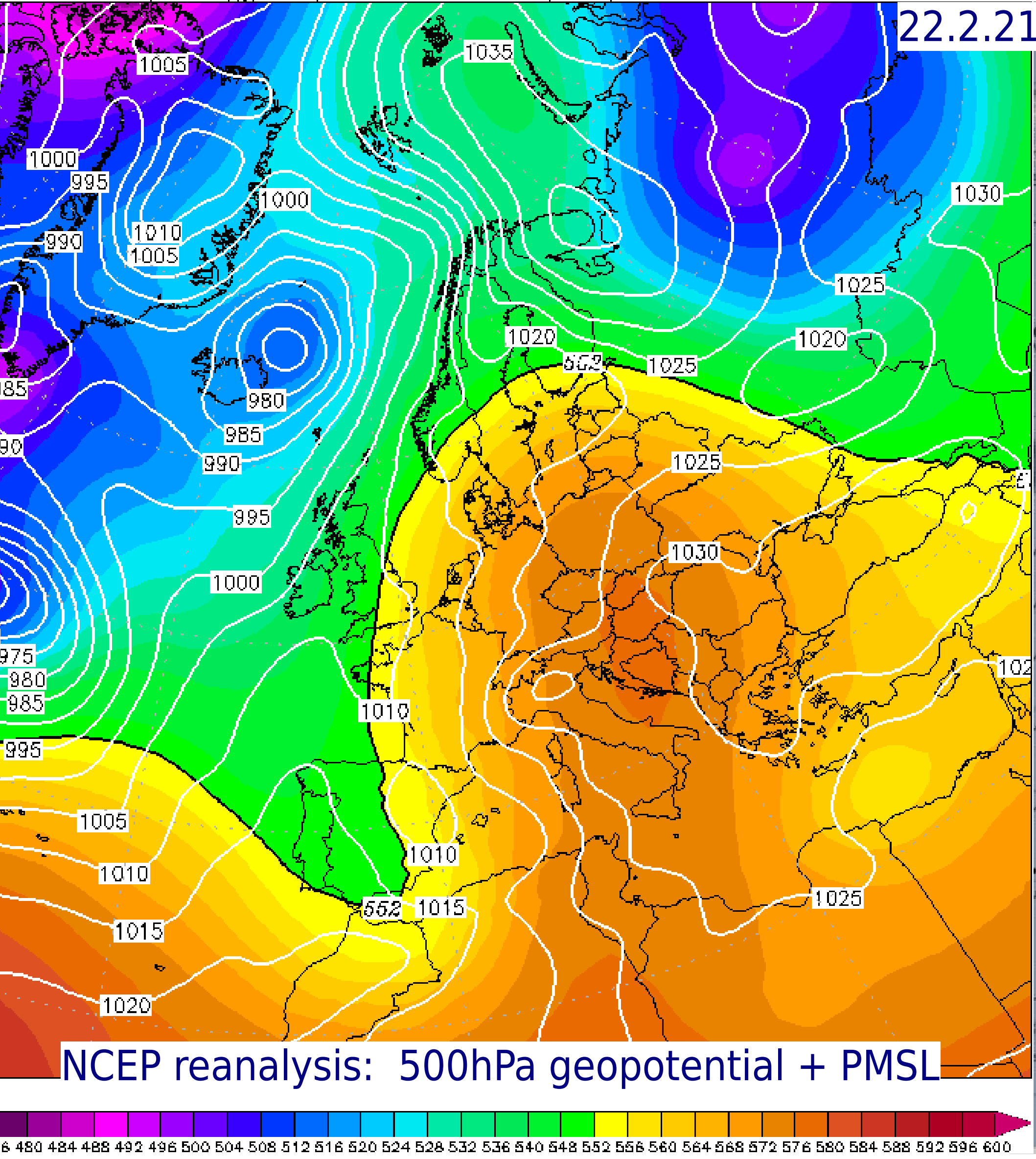
System for Integrated modeLling of Atmospheric coMposition (SILAM) is a global-to-meso-scale dispersion model developed in Finnish Meteorological Institute for prediction of atmospheric composition and air quality.

In this study, SILAM data are used for comparison.

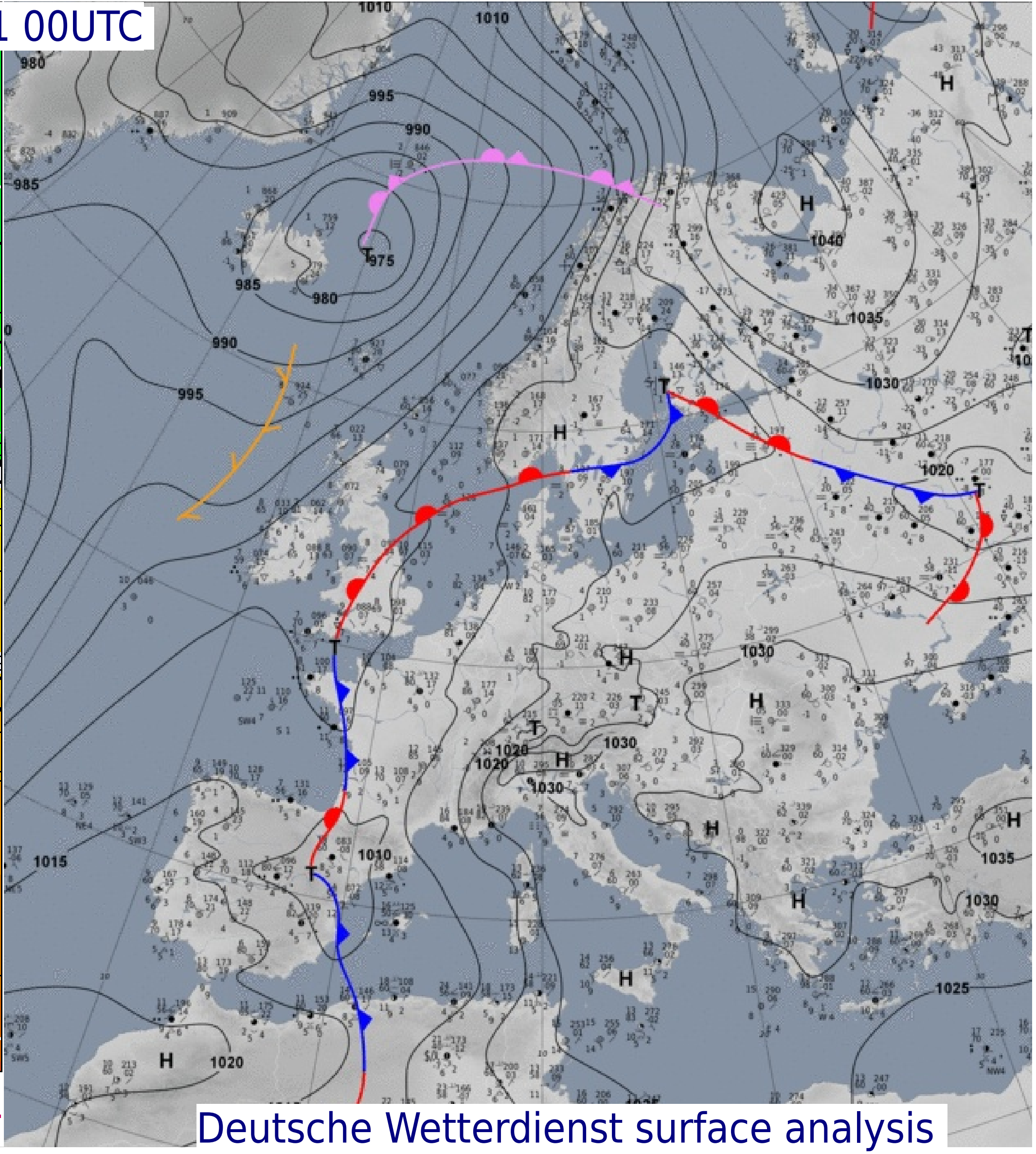
Contents

Helsinki sea ice

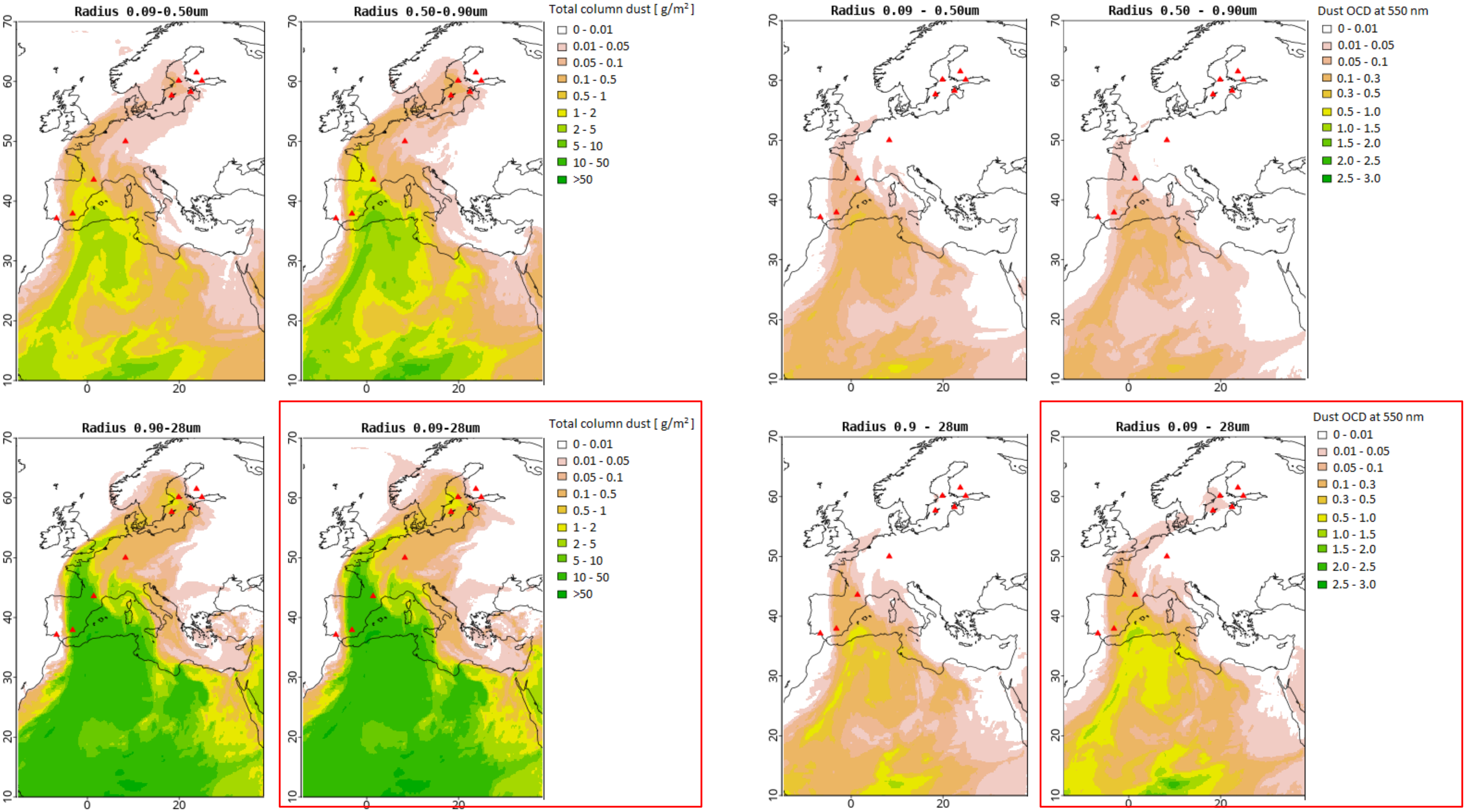
22.2.21 00UTC



NCEP reanalysis: 500hPa geopotential + PMSL



Deutsche Wetterdienst surface analysis



SILAM 21.2.21 12UTC : Dust load (g/m^2), left and total column optical depth (unitless), right

Triangles denote locations where aerosol profiles were picked from CAMS and SILAM data.

Helsingin Sanomat maanantaina 1.3.2021 A 9

KOTIMAA

Saharan hiekkaa pyydettiin lähettämään tutkimukseen

Sää | Hiekkaa tarvitaan kymmeniä grammoja jäädydinkokeita varten.

...io Pellinen STT

"Sitten nähdään, että kun tietynlaista hiukkasta pistetään sinne, missä lämmössä ja kosteudessa syntyy jääkiteitä."

Jos ne ovat tehokkaita jääytimiä, jäätä muodostuu Laaksosen mukaan jo silloin, kun suhteellinen ilmankosteus on juuri ja juuri sellainen, että jäätä voisi ylipäätään muodostua.

Laaksosen mukaan tällä hetkellä ymmärretään yllättävänkin huonosti sitä, millaisia hiukkasia 5–15 kilometrin korkeuksissa on ja mitkä niistä ovat tehokkaita ytimiä jääkiteille.

SAHARASTA tulee tuulten mukana harvoin hiekkaa Suomeen, mutta nyt ajoitus oli erinomainen.

Ilmatieteen laitoksella on Laaksosen mukaan syksyllä alkamassa tutkimusprojekti, jossa juuri tämänkaltaisia asioita tutkitaan. Toinen projekti on parhaikaa käynnissä.

"Tähän sattui nyt vähän tällainen onnenkantamoinen, että juuri sellaista tavaraa tuli tänne, mistä olemme kiinnostuneet."

Vaikka hiekkaa ei saataisi kerättyä tarpeeksi jäädydinkokeita varten, saatuja näytteitä tutkitaan esimerkiksi mikroskoopein ja muilla menetelmillä. Niistä joitakin tuloksia saadaan julki ehkä jo tulevina viikkoina.

"Nämä jäädydinkokeet vievät pidempään, mutta jos tavaraa tulee tarpeeksi, joitakin tuloksia meillä on parin kuukauden aikajänteellä. Jos tulokset ovat kelvollisia, ne julkaistaan jossain vaiheessa tieteellisessä kirjallisuudessa. Siihen menee suurin piirtein vuosi", Laaksonen sanoo.

Keräyskehotuksesta kertoi aiemmin Aamulehti.

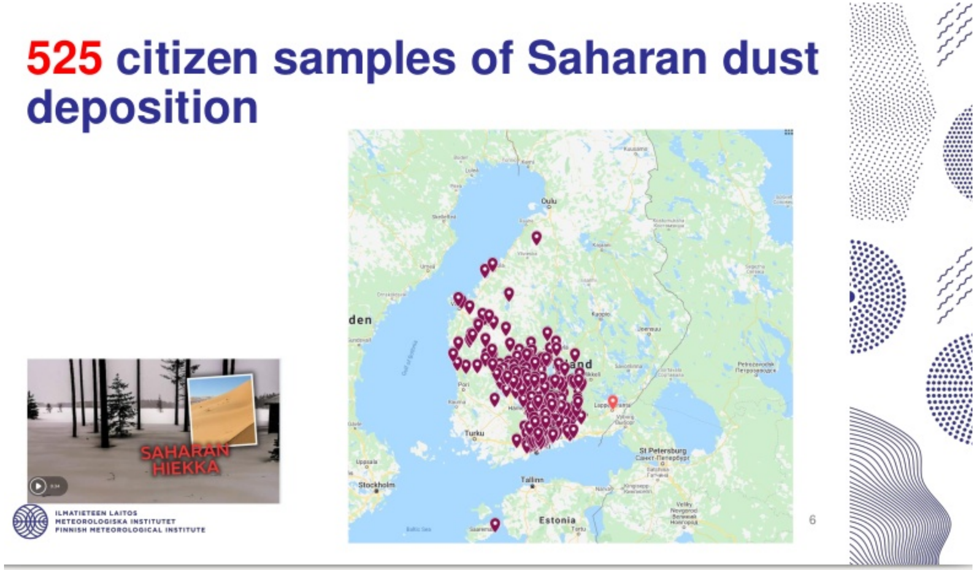
...kilometrin korkeuteen, muodostavatko ne tehokkaasti näiden yläpilvien jääkiteitä ympärilleen. Koska jos muodostavat, sillä on merkitystä siihen, millaisia niiden pilvien ilmastolliset ominaisuudet ovat maapallolle saapuvan auringonvalon kannalta", Laaksonen kertoo.

Poiminta

Näin keräämiseen voi osallistua

OHJEITA näytteenottoon ovat antaneet Ilmatieteen laitoksen tieteellinen johtaja Ari Laaksonen ja vanhempi tutkija Outi Meinander.

- Saharasta Suomeen lentäneestä hiekasta voi yhä yrittää kerätä näytteitä, sillä hiekkaa
- Kerää läikkien värjäämää pintalunta ruokalusikalla noin 2 desilitraa. Sulata ja suodata lumi huoneenlämmössä kahvin suodatinpaperin läpi. Lumen voi myös sulattaa toisessa astiassa ja kaataa veden suodattimeen. Kääri kuivunut suodatin folioon tai muovipussiin.
- Suodattamisen sijaan voit myös antaa 1 desilitran lunta



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, results analysed in:
Meinander et al.: African dust transport and deposition modelling verified through a citizen science campaign in Finland, (under review for Nature SciRep 2023)

Weather modeller’s questions

Do we know how remote dust influenced local weather?

What happens when we add dust into HARMONIE?

How sensitive is the weather model to aerosol input details?

How to improve aerosol usage in HARMONIE?

Can we afford for n.r.t. aerosols in HARMONIE?

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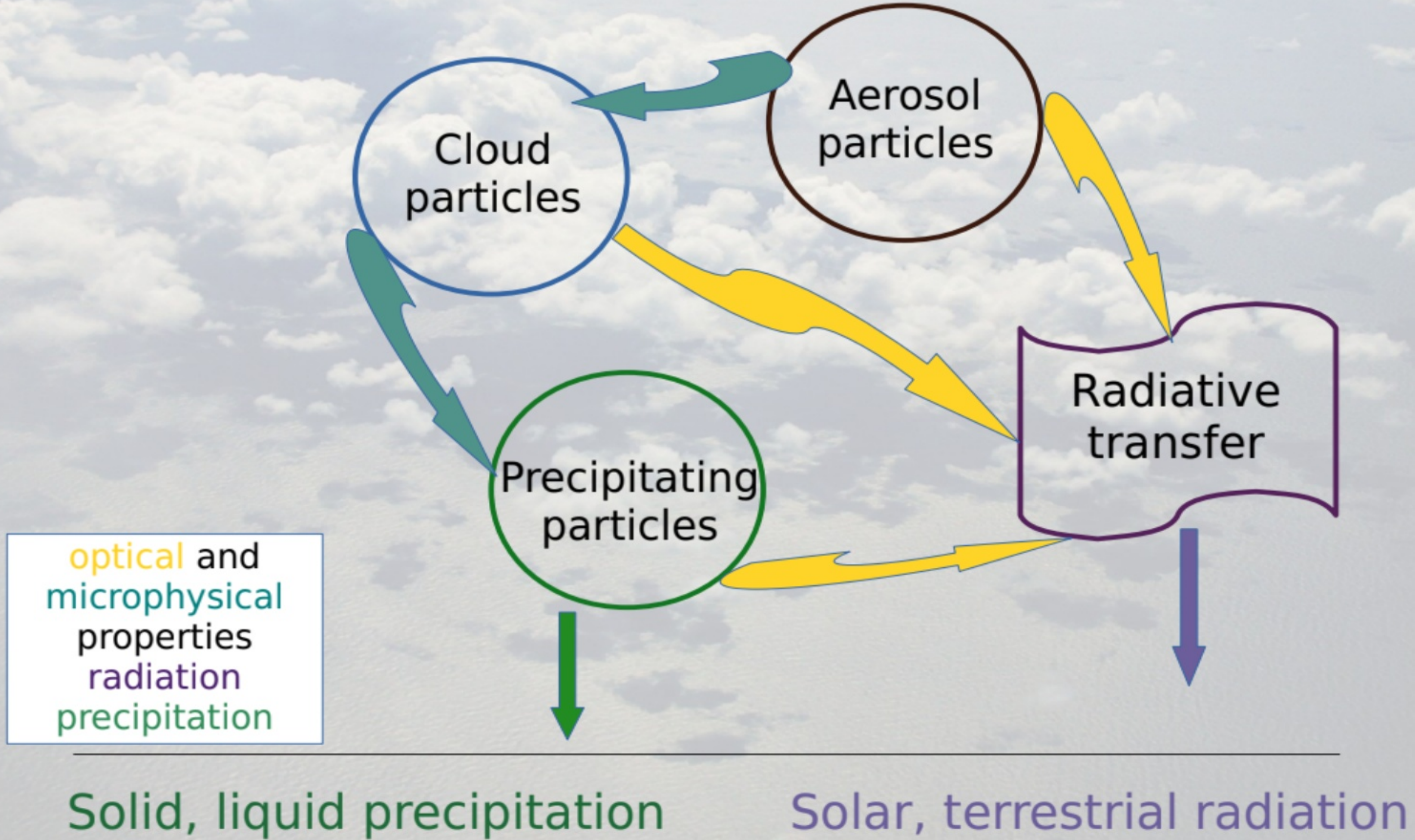
Parametrization of microphysics and optical properties



HARMONIE uses external aerosols as input

HARMONIE-AROME imports near-real-time
3D data on aerosol concentration from CAMS:

- Sea salt, desert dust, organic matter, black carbon, sulfate, ammonium and nitrate are included
- Fields are imported via horizontal boundary generation for the initial state of every forecast run
- Aerosols are advected during the forecast run, updated at boundaries, dust and sea salt sources and sinks are included

Dust transported from Sahara to Finland could be accounted for in a limited area NWP model because it was coupled to a global ACT model

Key variables of the parametrizations

Cloud microphysics:

Mass mixing ratio of hydrophilic and hydrophobic aerosol species →
liquid droplet and ice crystal number concentration →
specific content of cloud liquid, ice and precipitable rain, snow, graupel → precipitation

Radiation:

Aerosol mass mixing ratio and inherent optical properties →
aerosol optical depth → SW and LW radiation fluxes

Secondary aerosol effect on radiation:

liquid droplet number concentration → cloud droplet effective size

Contents

HARMONIE experiments

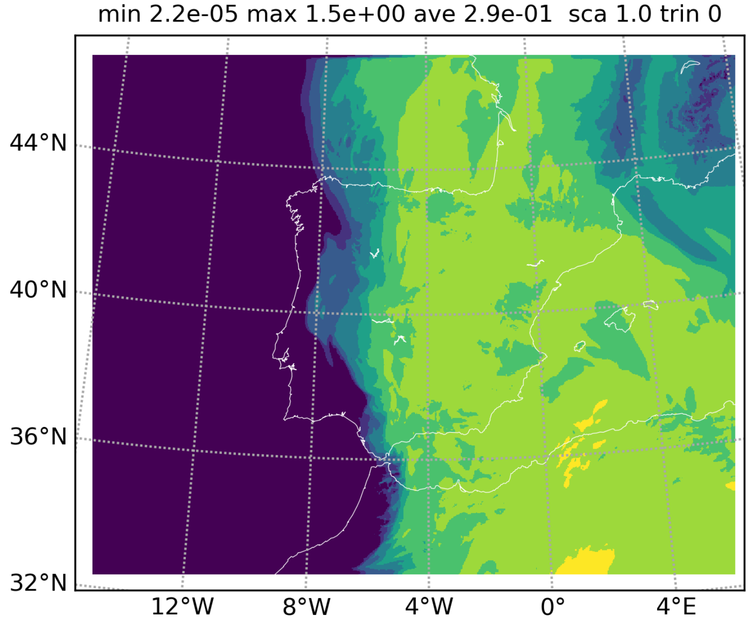
3D experiments with climatological and n.r.t. aerosol
over three European model domains

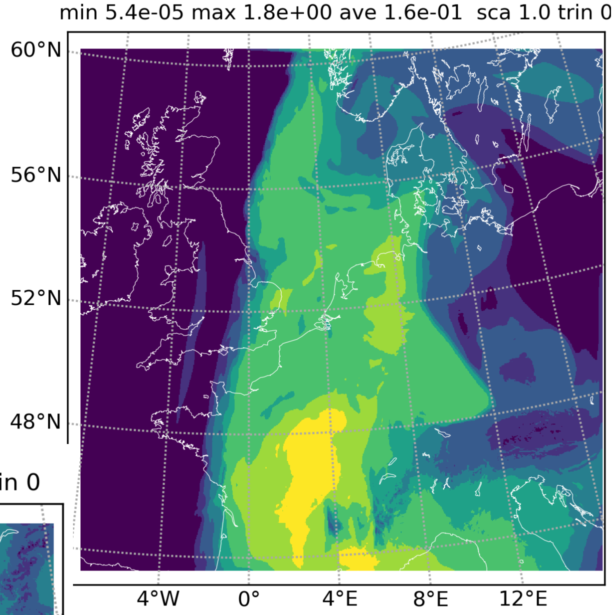
- Reference experiments with climatological aerosol
- Introducing all near-real-time aerosols or only dust
- Using default radiation scheme with secondary cloud-aerosol-interactions
- Using a single-band radiation scheme with advanced AIOPs but without secondary cloud interactions

Differences of radiation, clouds, precipitation, T_{2m} between experiments

Total column MMR (g/m^2) of the coarsest dust (radius 0.9–10 μm) CAMS via ACCORD

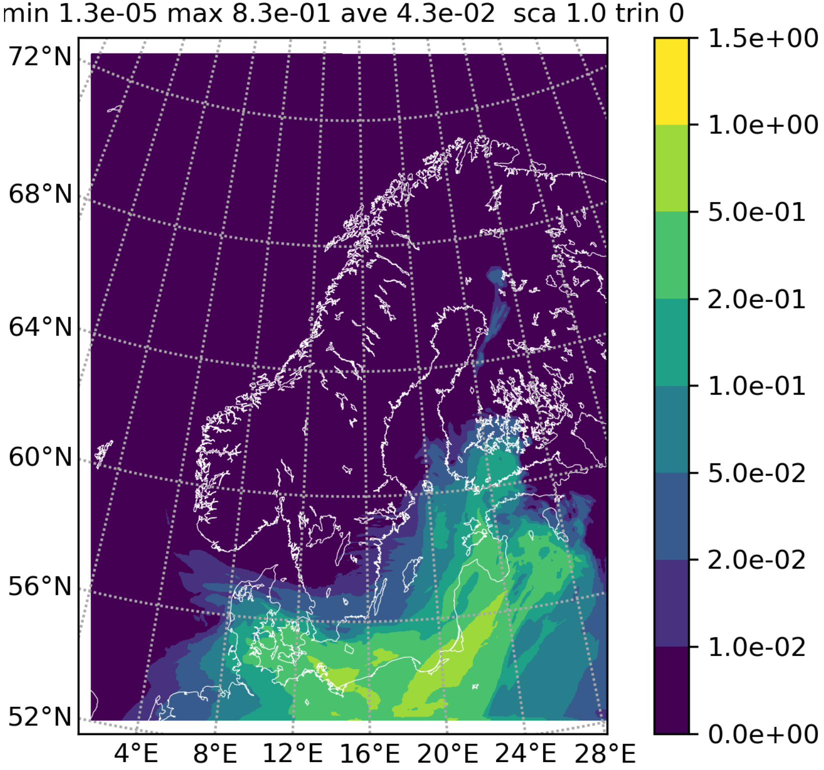
2021022100+12
AEMET Iberia





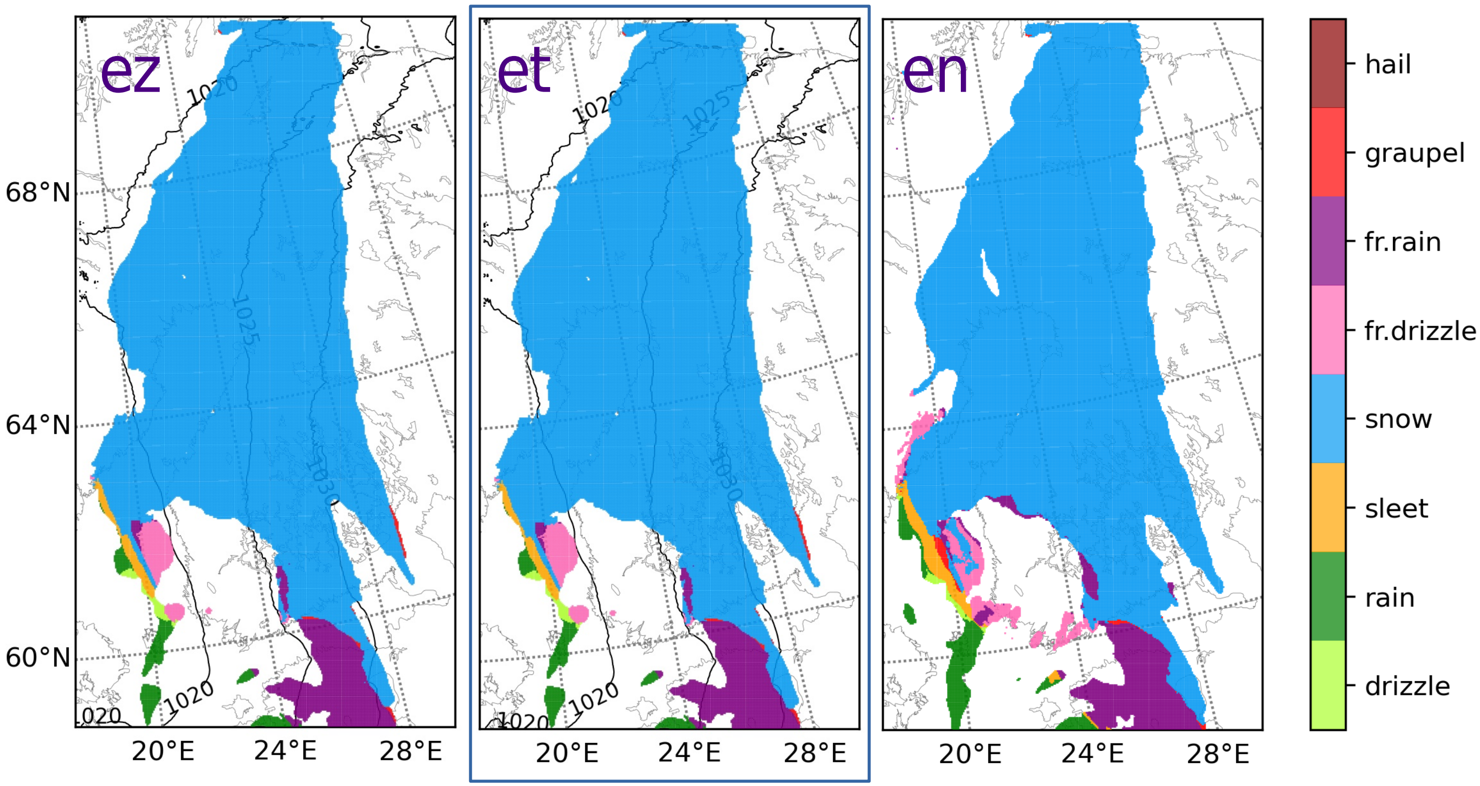
2021022200+12
KNMI Netherlands

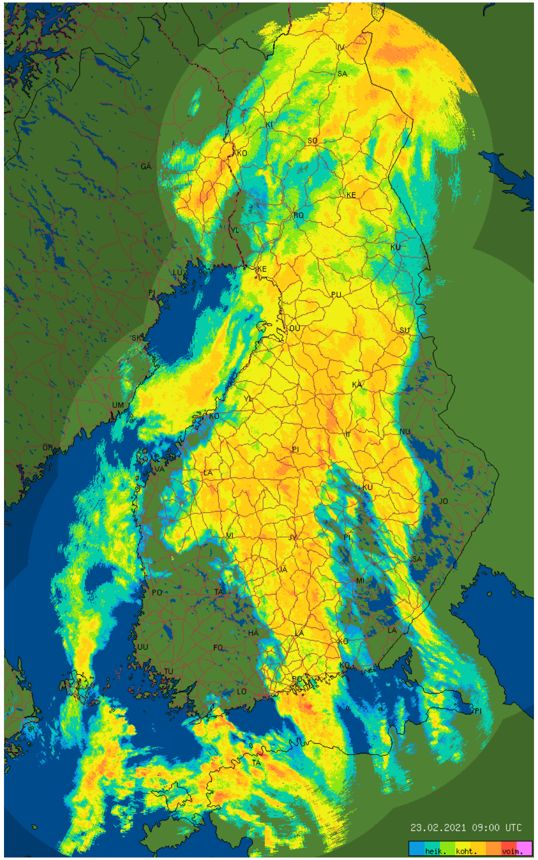
2021022300+12
MetCoOp Scandinavia



ACCORD accounts for dust and sea salt removal (and sources) during +12hour forecast, compared to original CAMS data at initial time of each forecast

Prevailing precipitation type on the 23rd of February 2021, fc 06UTC+03h



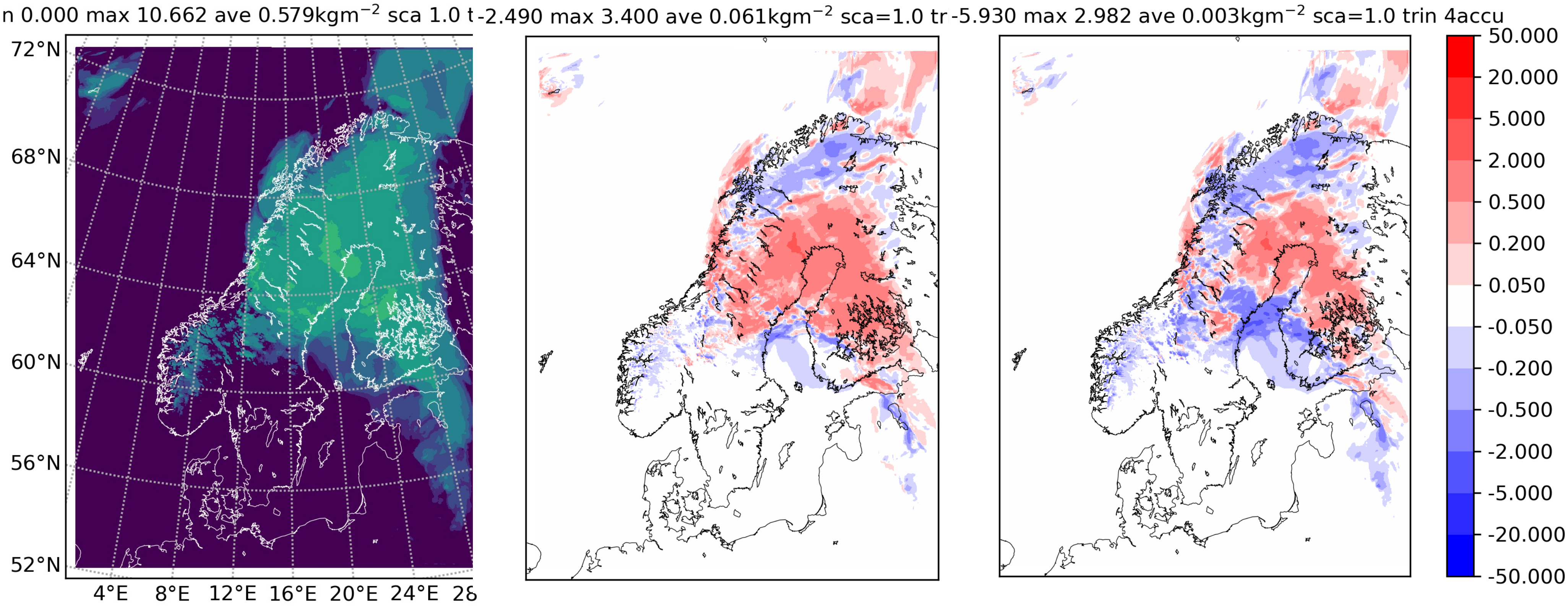


Only small differences in diagnostic precipitation type when aerosols influence the cloud microphysics parametrizations. All forecasts correspond well to radar precipitation distribution.

ez – no aerosol
et - clim AOD
en – CAMS n.r.t.

\+ default radiation scheme

Accumulated snowfall (kg/m²) 00-12
MetCoOp Scandinavia on 20210223

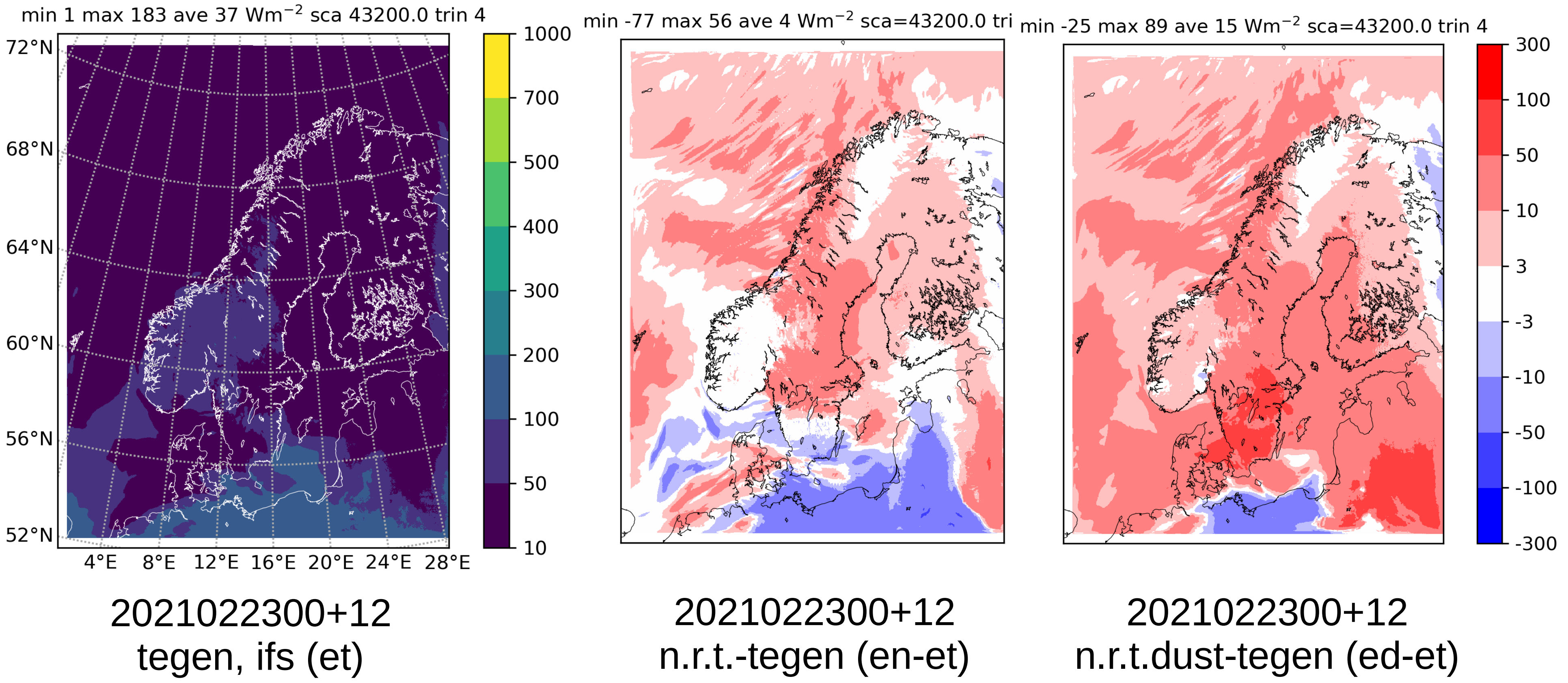


2021022300+12
tegen, ifs (en)

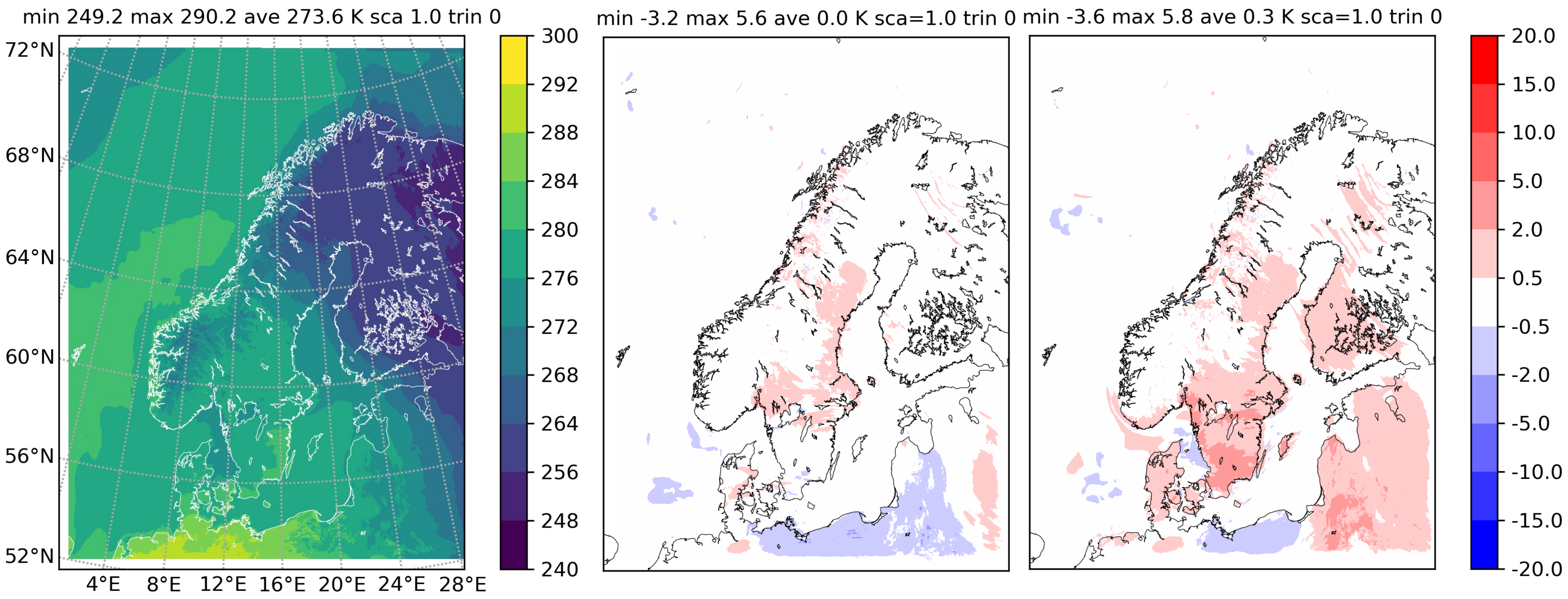
2021022300+12
n.r.t. - tegen, ifs (en-et)

2021022300+12
n.r.t. dust – tegen, ifs (ed-et)

Average SWDN (W/m²) at the surface 00-12
MetCoOp Scandinavia on 20210223



Screen-level temperature at 12
MetCoOp Scandinavia on 20210223



2021022300+12
tegen, ifs (et)

2021022300+12
n.r.t.-tegen (en-et)

2021022300+12
n.r.t.dust-tegen (ed-et)

Quick remarks on 3D experiment results

Distribution of total precipitation and dominating precipitation type did not change much when introducing n.r.t. aerosol instead of climatology

SW and LW radiation changed due to direct (Spain, less clouds) aerosol impact and due to clouds (Scandinavia, where clouds and precipitation dominated)

Assumptions on cloud-radiation-aerosol microphysics influenced significantly radiation and relative magnitude of snow/graupel/liquid precipitation fluxes when n.r.t. aerosols were used

A lot of interactions, assumptions – not easy to reach firm conclusions!

Single column sensitivity experiments

MUSC, the ACCORD single-column model, allows for flexible light-weight experimenting including model physical parametrizations only:

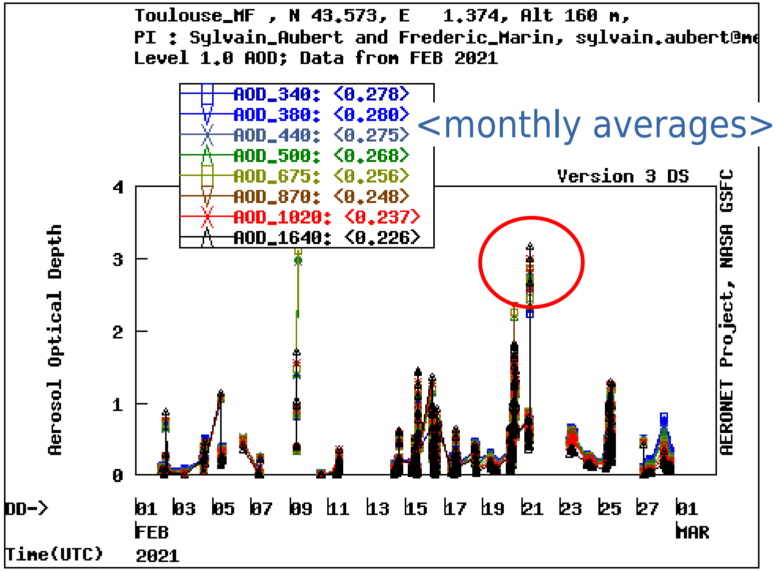
Modify input profiles picked from 3D model experiments

Modify parametrizations via namelist choices and source code updates

Surface interactions are fully included and incoming solar radiation changes in time but model dynamics is excluded and aerosols do not evolve

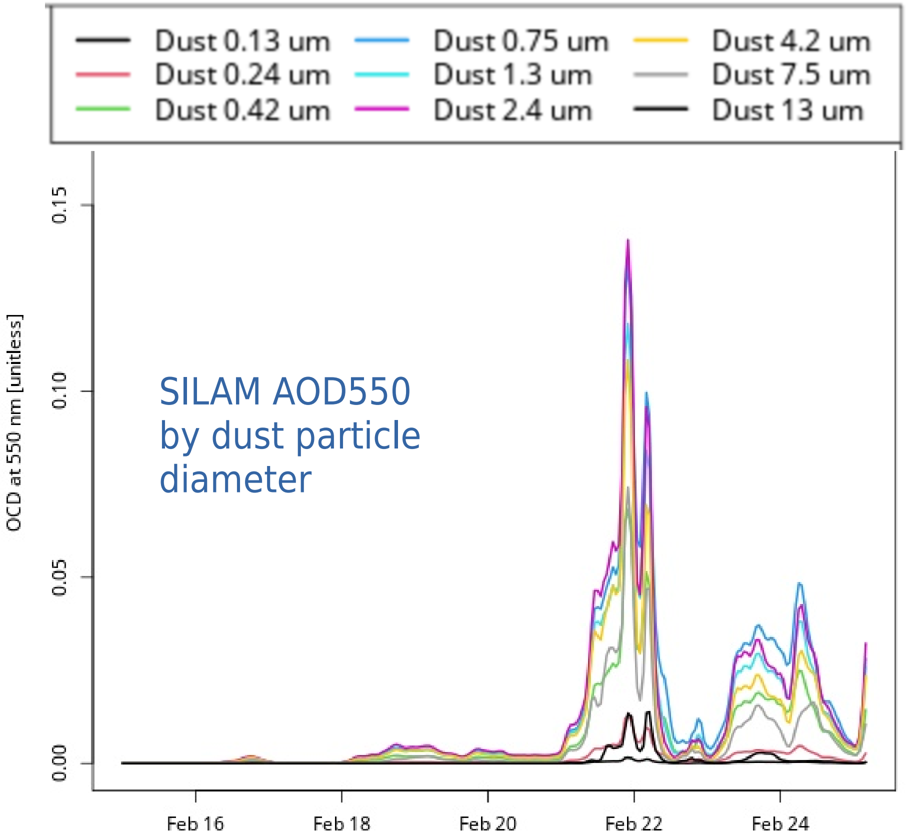
MUSC experiments allow for sensitivity studies but do not provide realistic output to compare with observations. This is a developer's tool!

Toulouse 21 February 2021



Observed total-column AOD, February 2021
https://aeronet.gsfc.nasa.gov

SILAM and CAMS dust AOD550 = ca.0.2



SILAM and CAMS grid-average dust AOD550 is an order of magnitude smaller (0.2) than observed maximum all-aerosol AOD550 point value (3)

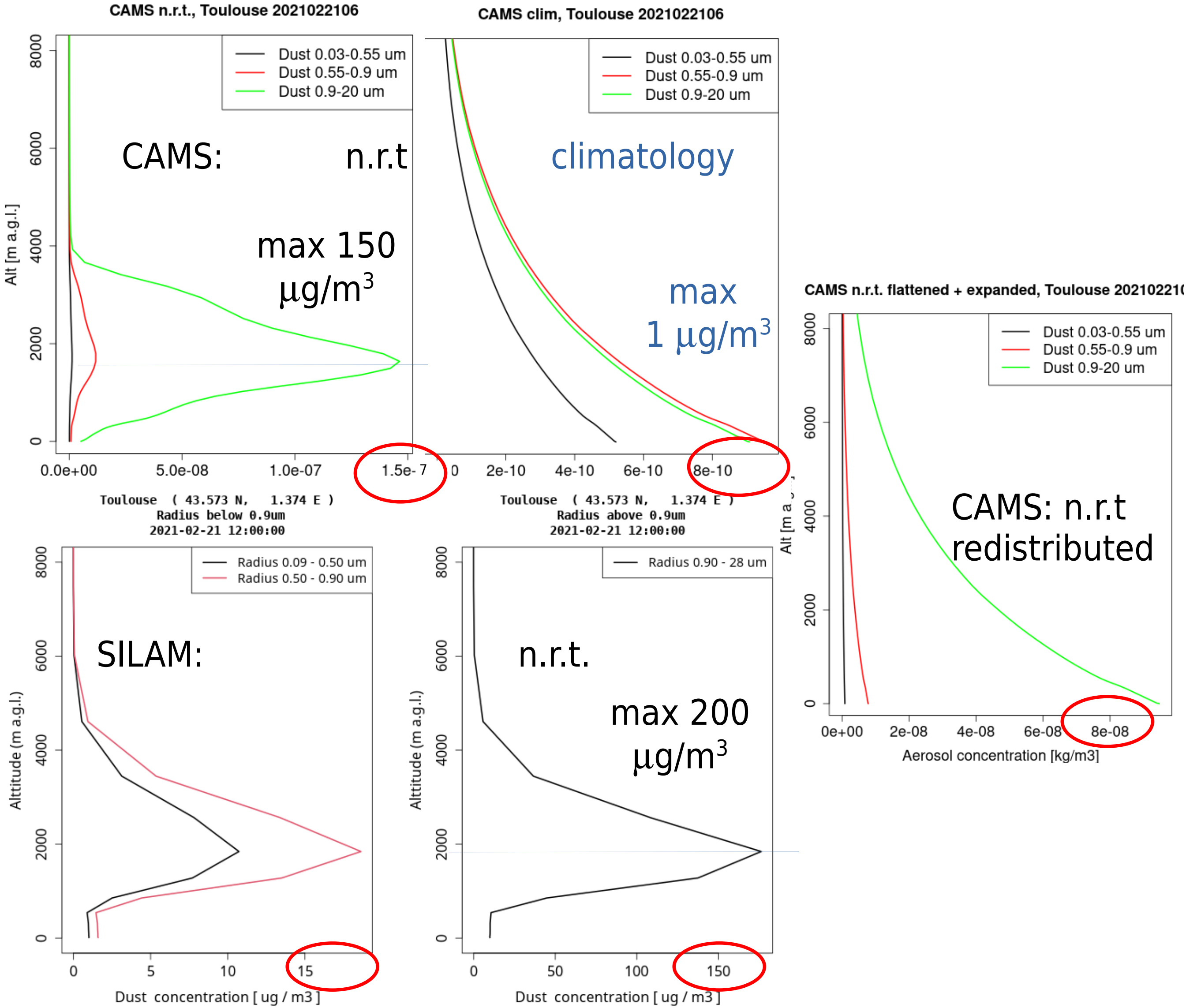
Models' space and time scales are different from those of the point observations
Only dust from the models but all aerosols in the observation (CAMS all-aerosol AOD550 was 0.3)
(Assumed) dust size distribution influences optical depth

Toulouse
21 February 2021

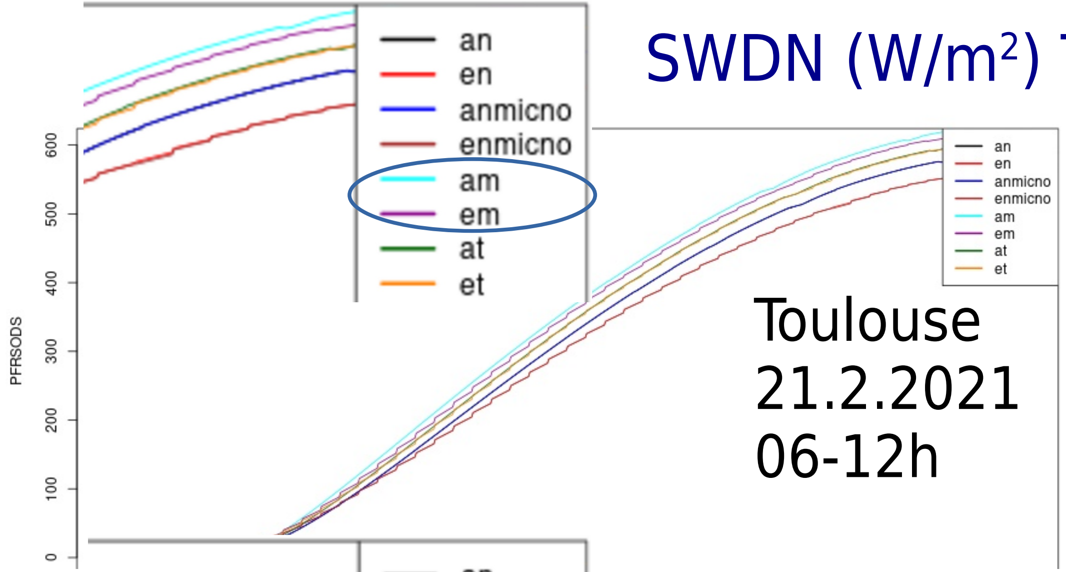
Climatological dust concentration was very different from simulated n.r.t. concentration:

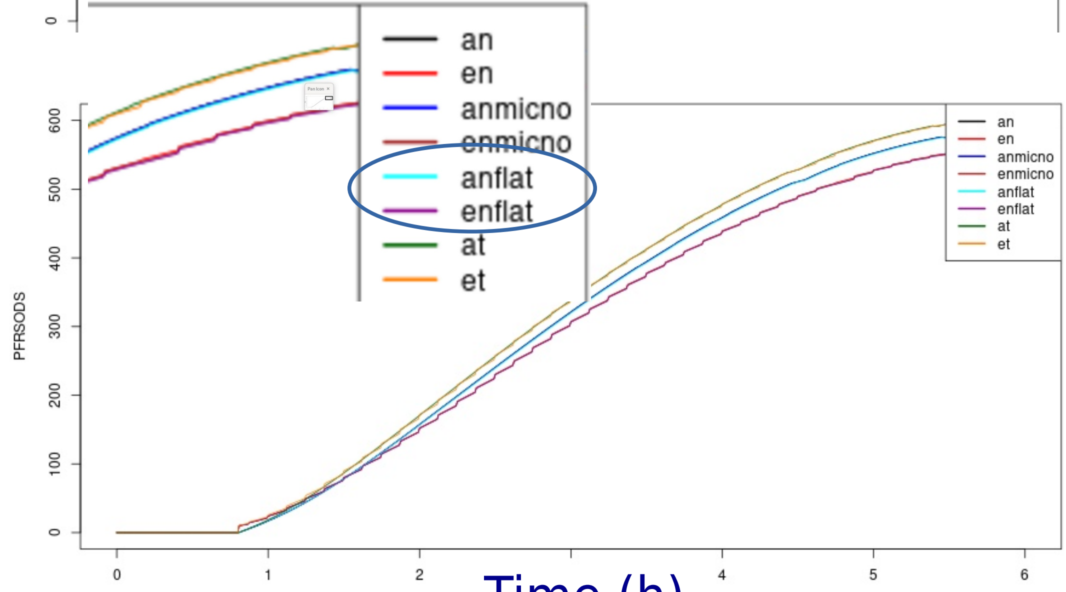
- Total column value
- Vertical distribution
- Size distribution

Try MUSC experiments with CAMS dust:
n.r.t. v.s. clim
redistributed n.r.t.



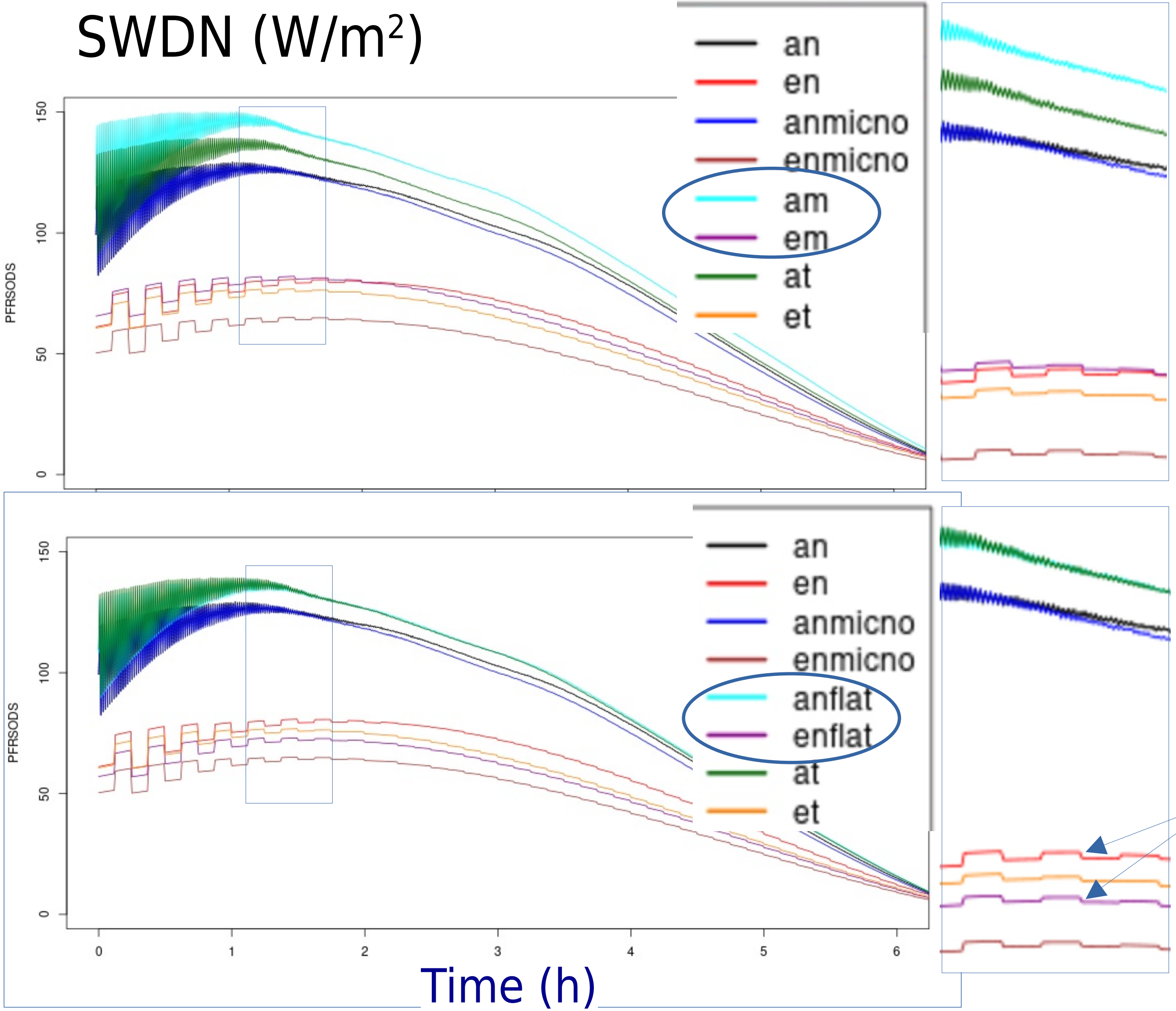
SWDN (W/m^2) Toulouse 21.2.2021 06-12h MUSC





In Toulouse, there were no clouds or precipitation. Differences are due to the different aerosol load and different radiation schemes. Vertical distribution of dust did not really influence the results.

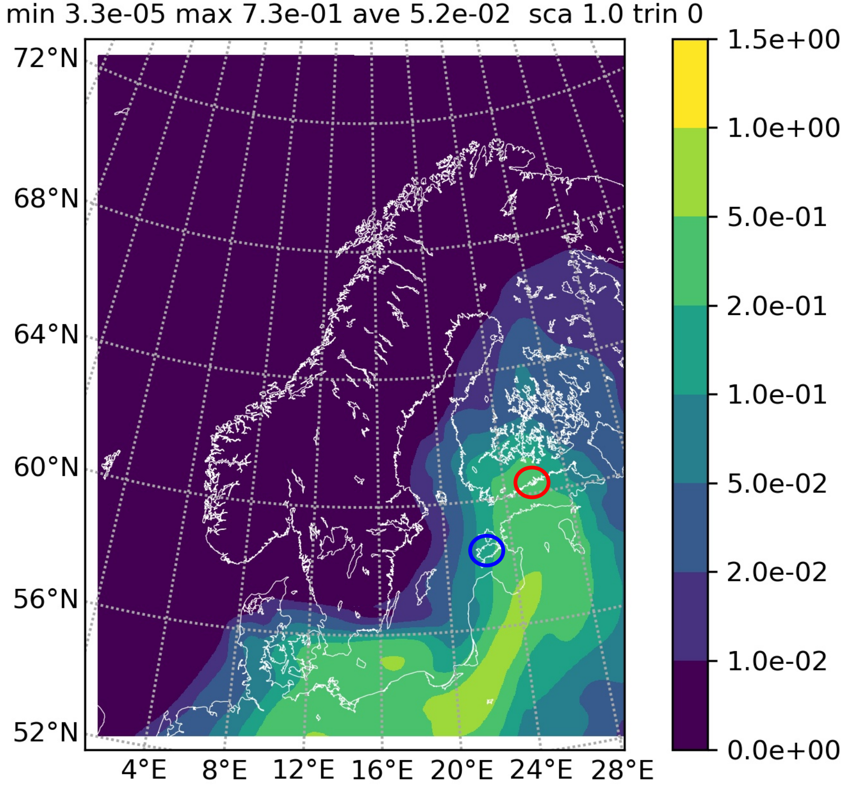
an= near-real-time aerosol + acraneb
en= near-real-time aerosol + IFS radia
annomicro and ennomicro = no aerosol influence on cloud microphysics allowed
am = climatological aerosol + acraneb
em = climatological aerosol + IFS radia
anflat and enflat = n.r.t. aerosol total-column MMR redistributed like clim.dust
at and et = tegen AOD550 (default)



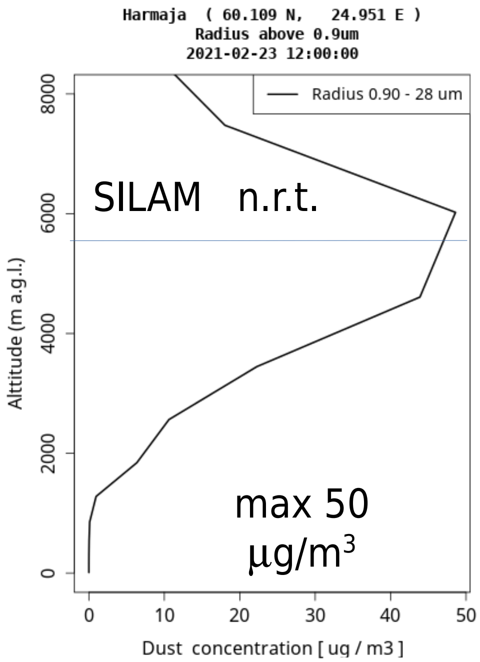
Kuressaare (on Estonian island Saaremaa) 23.2.2021 09-15h MUSC

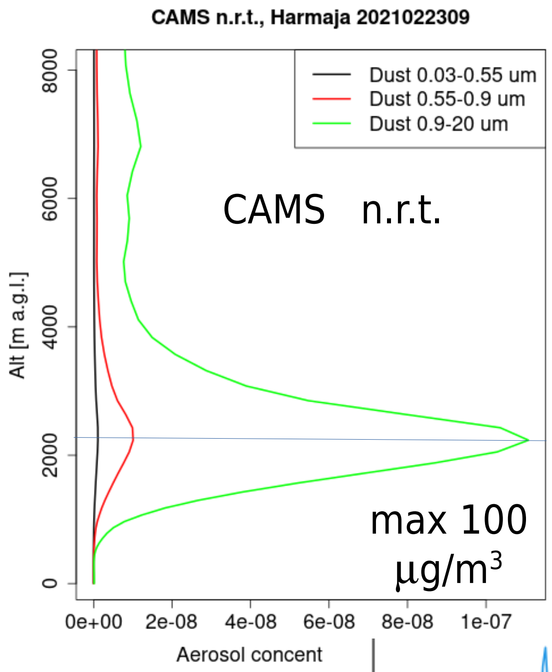
In Kuressaare, there were clouds and precipitation (rain). Radiation changes are mainly due to different aerosol load and cloud and cloud-aerosol-radiation parametrizations. Vertical distribution had a minor impact with IFS radiation.

Harmaja 23 February 2021

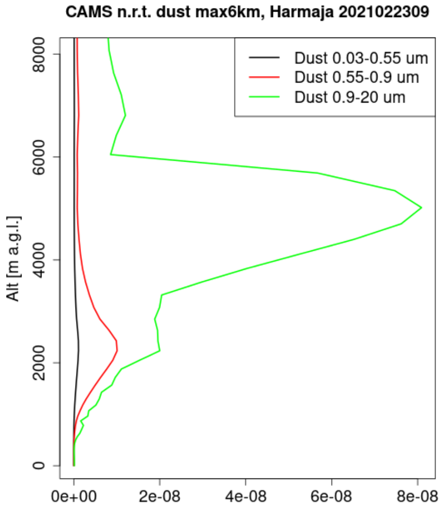


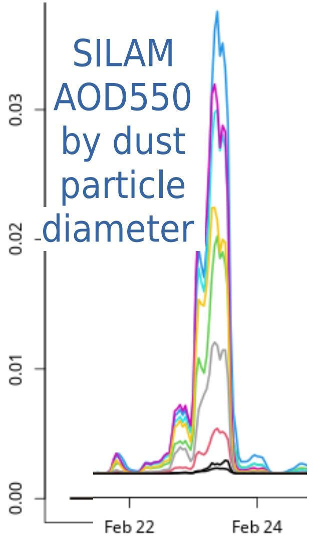
Total column MMR (g/m²) of the coarsest dust (radius 0.9–10 µm) CAMS via HARMONIE 12UTC

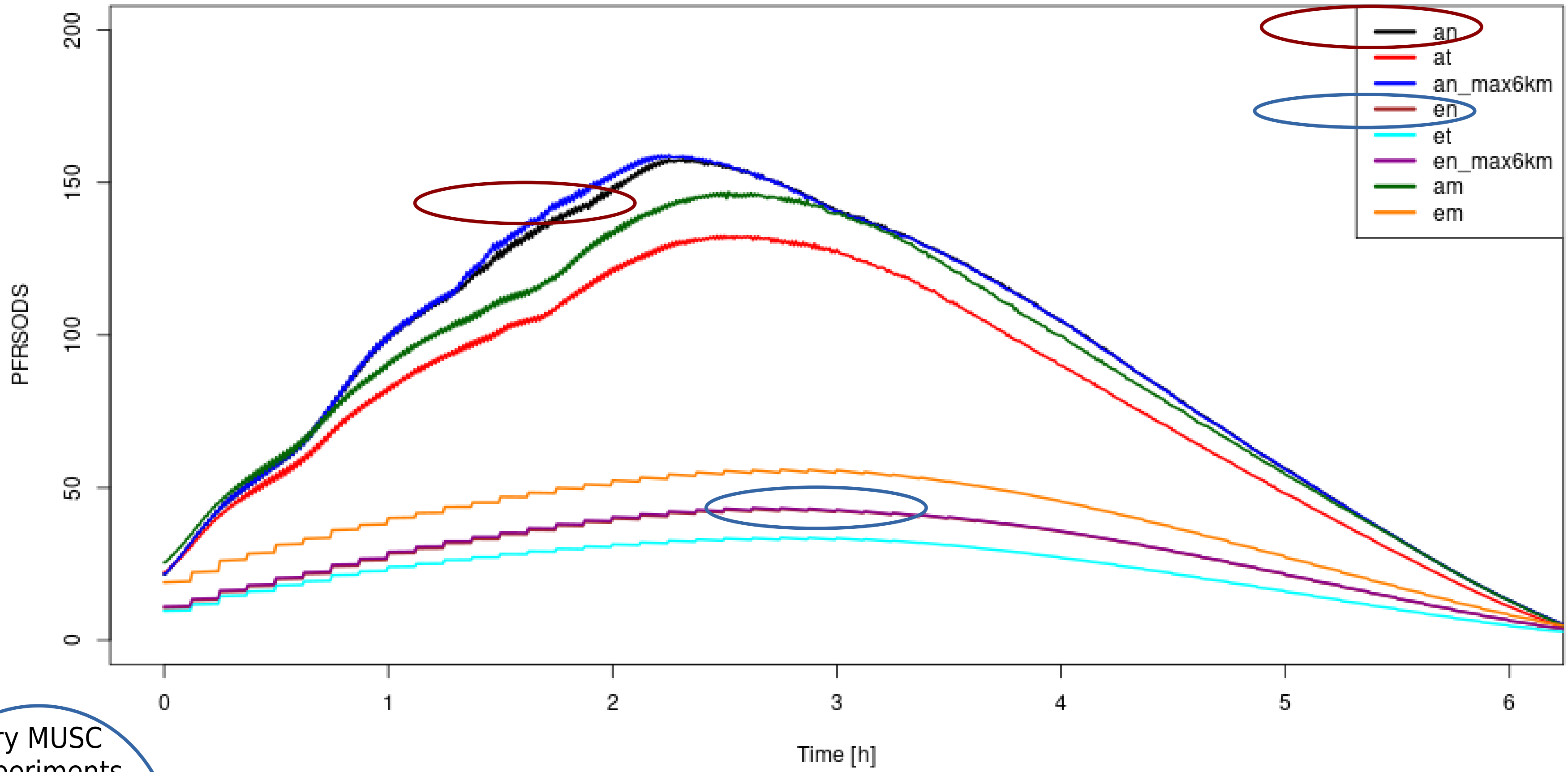




Try MUSC experiments with CAMS n.r.t. dust maximum moved from 2300 m (orig) to 5500 m (as by SILAM)

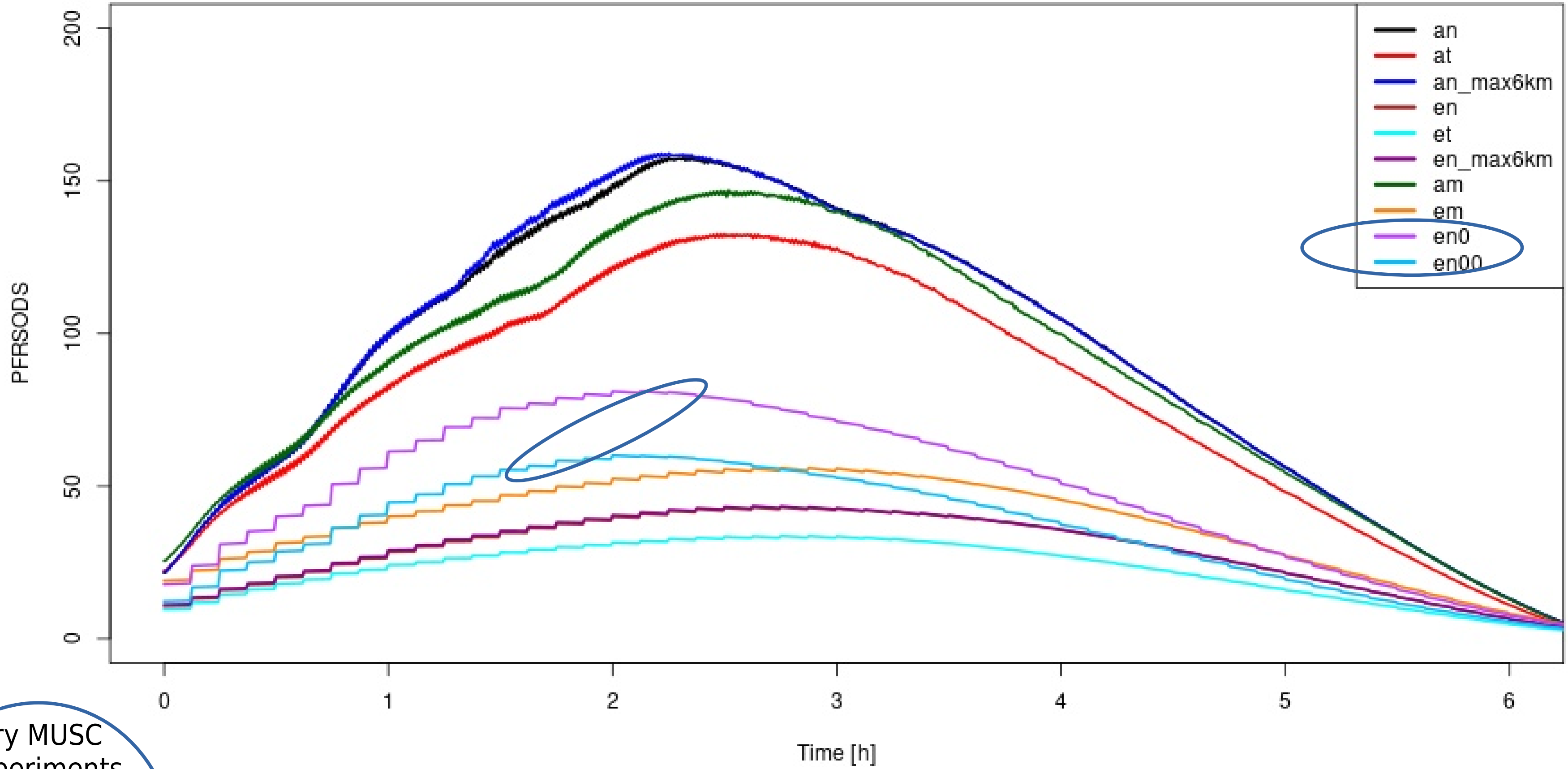






Try MUSC experiments with CAMS n.r.t. dust maximum moved from 2300 m (orig) to 5500 m (as by SILAM)

Difference due to level-of-maximum change was insignificant with acraneb radiation scheme, non-existent with IFS radiation → other differences dominate in this case



Try MUSC experiments with CAMS n.r.t. dust maximum moved from 2300 m (orig) to 5500 m (as by SILAM)

Two new curves show the impact of excluding graupel and snow (en0) and also using the default constant liquid droplet effective size instead of allowing for n.r.t. aerosol impact (en00) in IFS radiation scheme

Remarks on single column sensitivity experiments

Near-real-time aerosol distribution was very different from climatology: Total dust load was up to 100 times larger, maxima well above surface (local sources seem to dominate in climatology!).

Modifying vertical distribution of dust to exponential from surface or raising the maximum concentration level higher had a minor impact compared to the different aerosol load, and seen only when clouds were involved

Use of radiation and cloud microphysics schemes with different assumptions on cloud-radiation-precipitation interactions led to larger differences than modification of the aerosol input profiles: quite a lot of modelling uncertainties

Contents

Introduction

The case of Saharan dust in Finland

Aerosols in HARMONIE-AROME

HARMONIE experiments and results

<u>Concluding remarks</u>

Do we know how remote dust influenced local weather?

- we saw impact on precipitation type and radiation, but depending on cloud parametrizations

What happens when we add (only) dust into HARMONIE?

- radiation changes directly; impact of (hydrophobic) dust via cloud ice needs more studies

How sensitive is the weather model to aerosol input details?

- vertical distribution matters clearly less than total concentration; impact of assumed size distribution, aerosol type requires further studies

How to improve aerosol usage in HARMONIE?

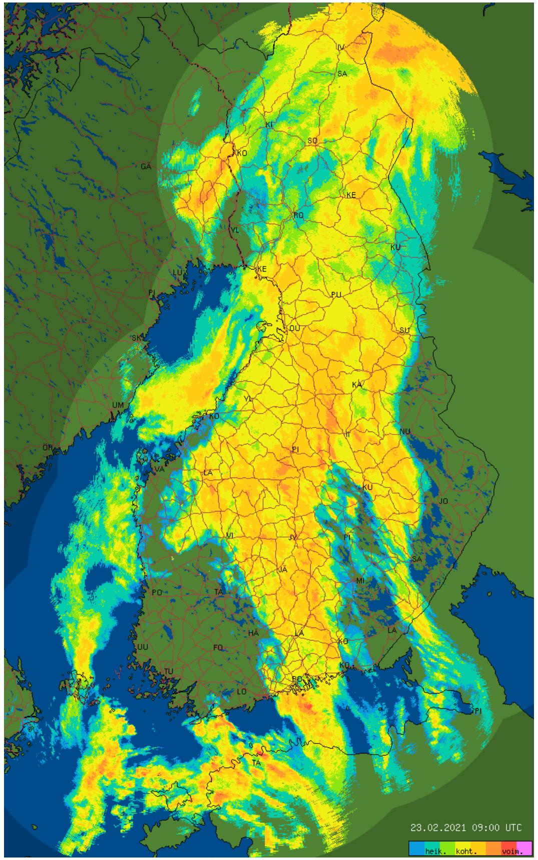
- to understand, reduce and control uncertainty; cloud particle size for radiation

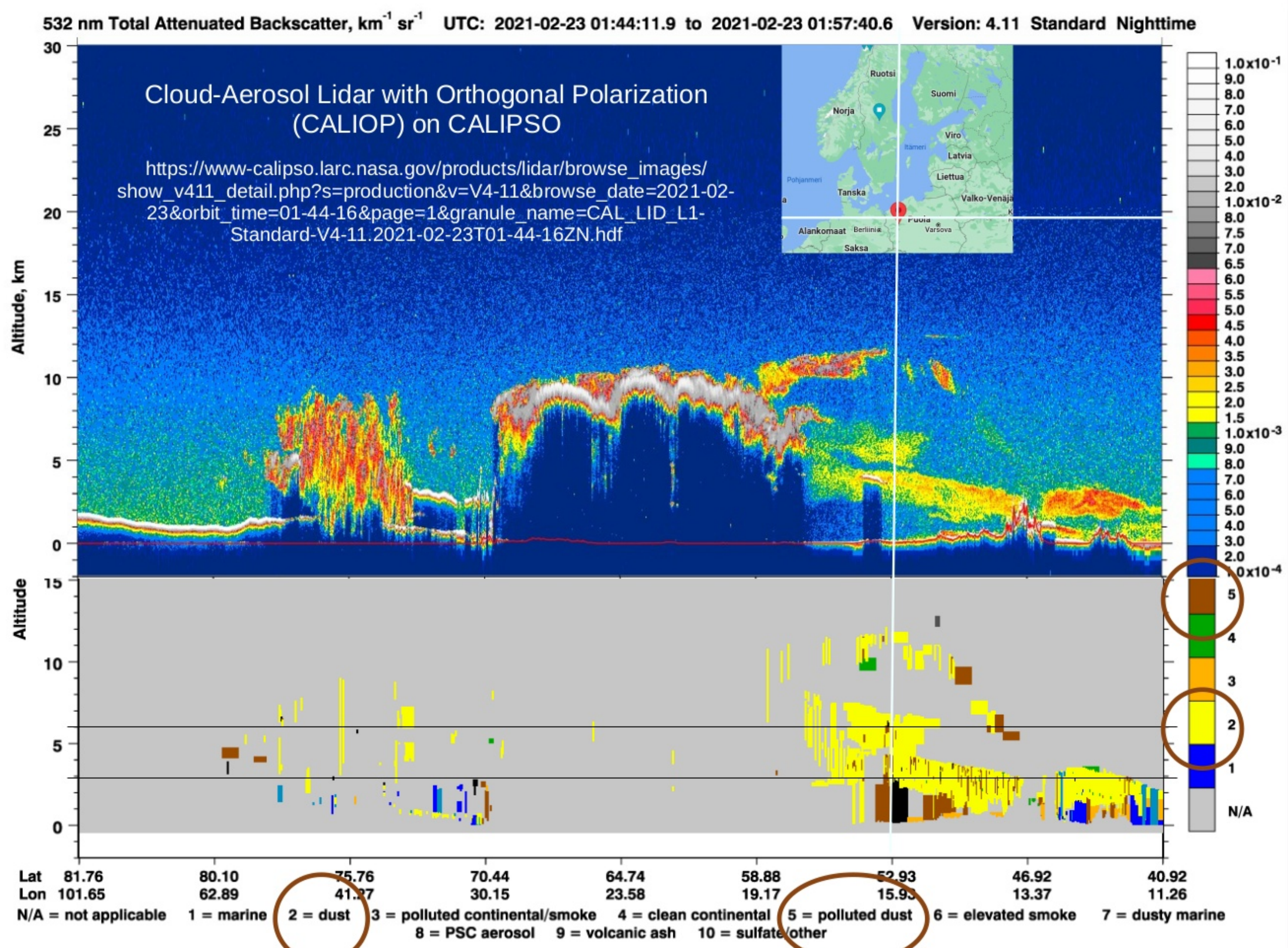
Can we afford for n.r.t. aerosols in HARMONIE?

- consider aerosols on-demand or flatten the total 3D concentrations to 2D fields and redistribute exponentially in vertical?

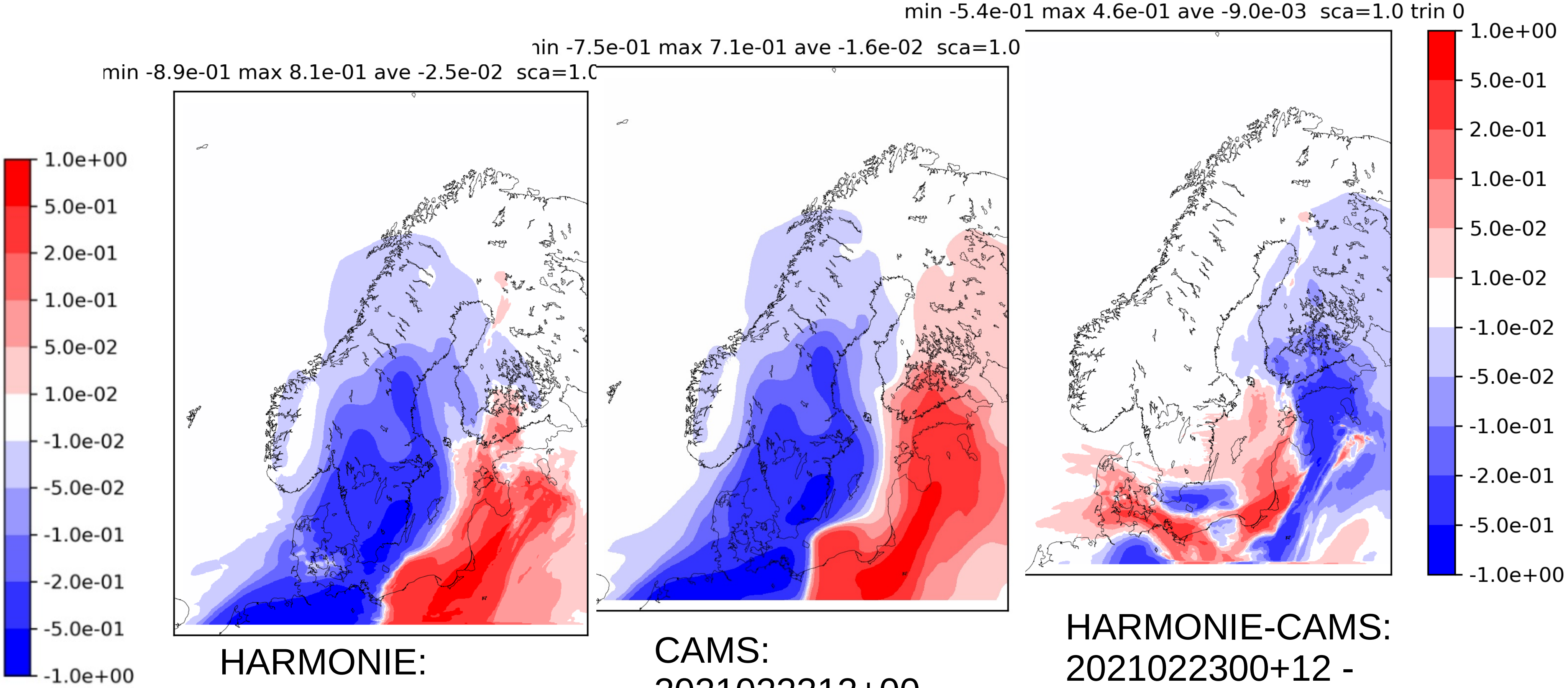
Thank you for attention!

Thank you for listening!





Total column MMR (g/m²) of the coarsest dust (radius 0.9–10 μm), Forecast differences, MetCoOp Scandinavia on 20210223



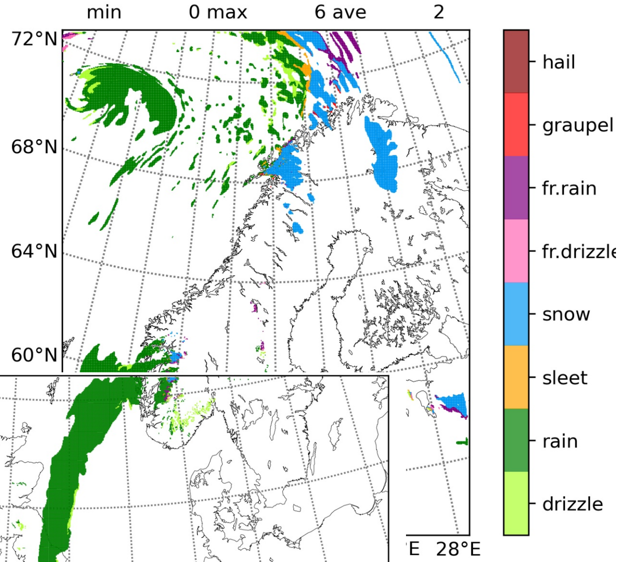
HARMONIE:
2021022300+12 -
2021022300+00

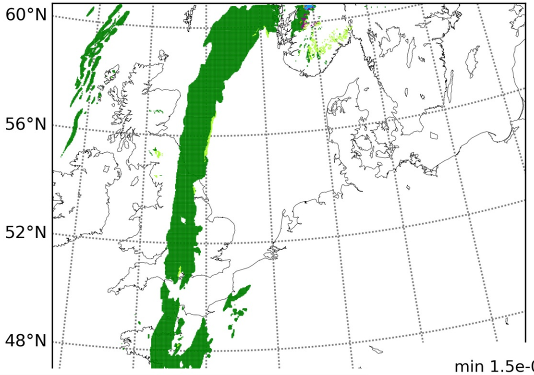
CAMS:
2021022312+00 -
2021022300+00

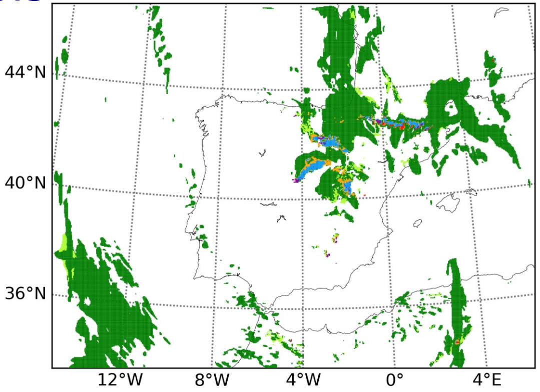
HARMONIE-CAMS:
2021022300+12 -
2021022312+00

Diagnostic precipitation type on the day before event in Helsinki

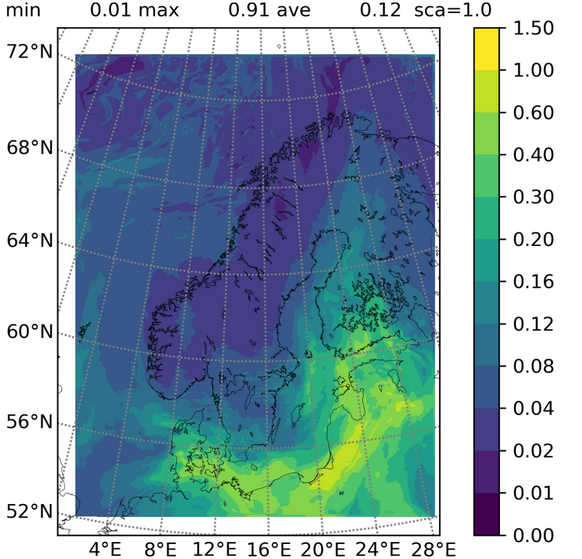
HARMONIE-AROME forecasts on 22 February 2021 006+03h include n.r.t. aerosols



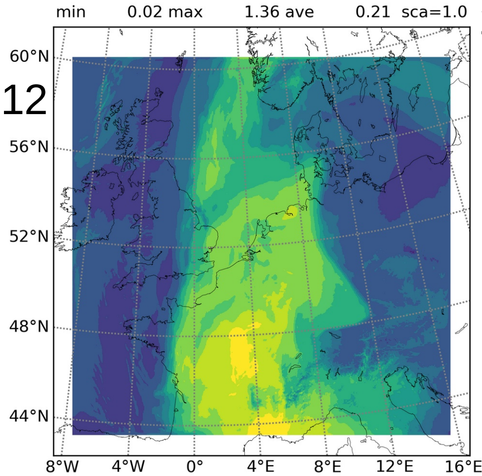




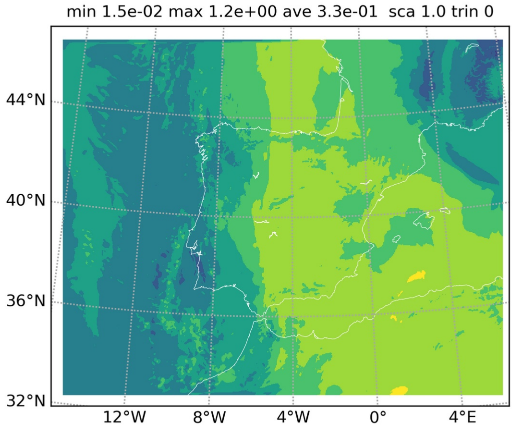
Total column weighted shortwave aerosol optical depth (unitless), CAMS via HARMONIE



2021022300+12

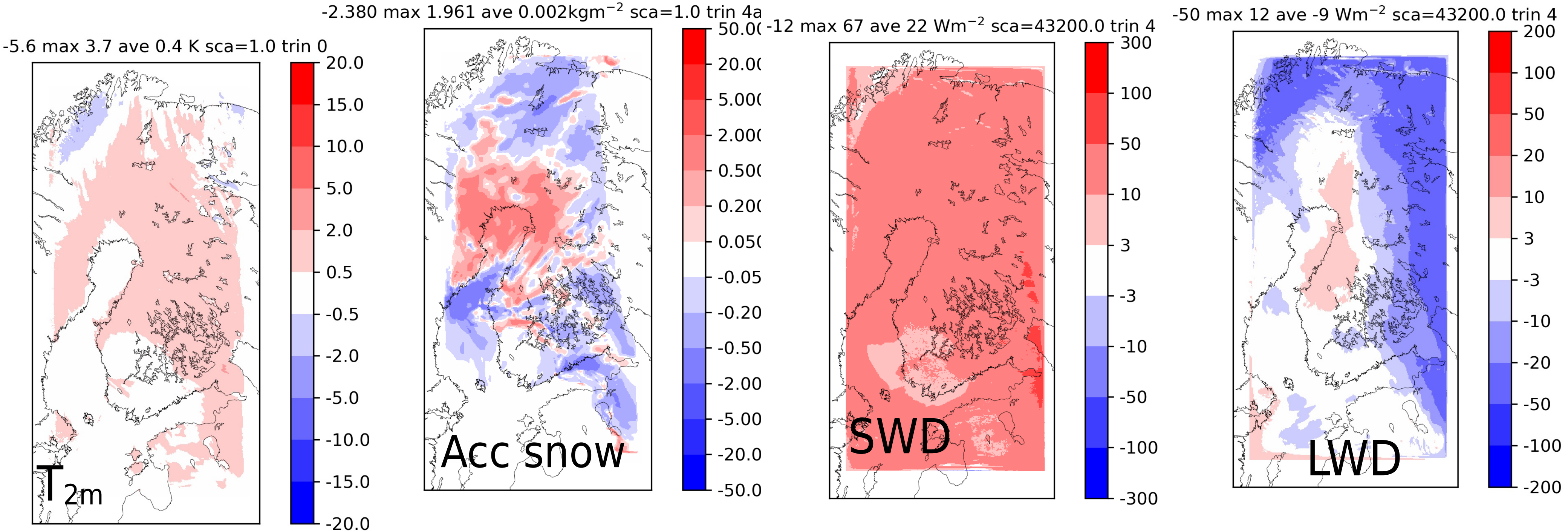


2021022200+12



2021022100+12

HARMONIE contains dust and sea salt removal (and sources) during +12hour forecast, compared to original CAMS data at initial time of each forecast



23 Feb 2021 00 UTC+12h

Differences between experiments (n.r.t. with acraneb2) - (Tegen with default IFS)

These differences are related to aerosol impact on cloud microphysics
and different radiation schemes that treat clouds and aerosols in different way