ACCORD

A Consortium for COnvection-scale modelling Research and Development

Excellence for NWP

Helsinki aerosol studies

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FMI Finland IMGW Poland DHMZ Croatia AEMET Spain
CHMI Czechia ONM Algeria

ACCORD All-staff workshop
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Contents

ACCORD aerosols

Where to take the aerosols from?

Aerosol climatology has been used for years
for radiation parametrizations. Now we can import
near-real-time aerosols from global chemical transport models
like CAMS/IFS-chem, also for cloud parametrizations.

How to parametrize the direct and indirect radiation effects?

Improvement of aerosol radiation transfer
is ongoing in the framework of several radiation schemes:
default IFS, acraneb2, hlradia, ecRAD.

How to handle the aerosols in cloud microphysics?

Studies related to liquid and solid cloud particles and precipitation
are ongoing within two microphysics shemes: default ice3 and LIMA

cy43h2_
rontu_aerad

Aerosol input

Aerosol mass mixing ratios (MMRs)
- from CAMS reanalysis via m-climate files (2D)
- CAMS near-real-time (n.r.t.) data imported via boundary files (3D)

Radiation

- MMRs converted to Tegen AOD550 for the default IFS radiation
- Run-time optical properties of aerosol mixture derived from MMRs and AIOPs for the single-band acraneb2 and hlradia

Cloud microphysics

- cloud droplet generation for default rain-ice scheme from condensation nuclei based on n.r.t. MMRs
- possible use of number of condensation nuclei in IFS radiation for droplet size parametrization

experiment on

pre-CY46h1_

nrtaer

Aerosol input

Aerosol mass mixing ratios (MMRs)

- from CAMS reanalysis via m-climate files (2D)
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Cloud microphysics

- cloud droplet and ice generation for default rain-ice scheme from condensation nuclei based on n.r.t. MMRs
- possible use of cloud droplet number in IFS radiation for droplet size parametrization

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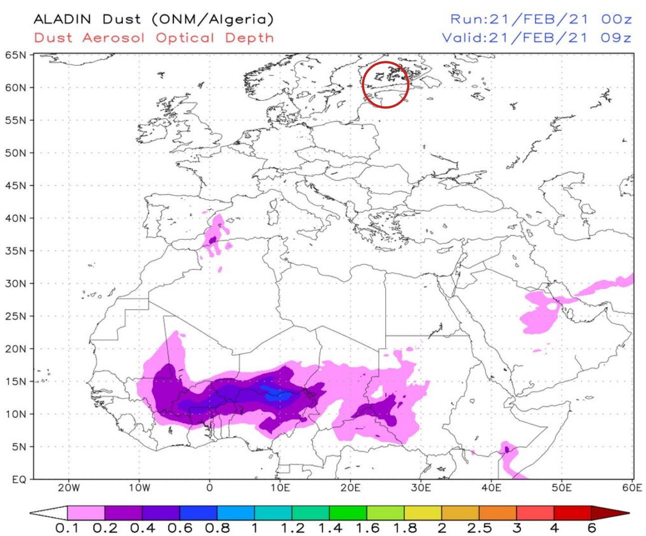
From Sahara to Helsinki, February 2021

Murcia 19 Feb 2021 towards south. Photo Jakob Lödjquist

Helsinki sea ice on 23 Feb 2021 10 UTC
Photo Laura Rontu

Helsinki sea ice on 15 UTC 25 Feb 2021 Photo Laura Rontu

ALADIN-DUST forecasts from ONM Algeria



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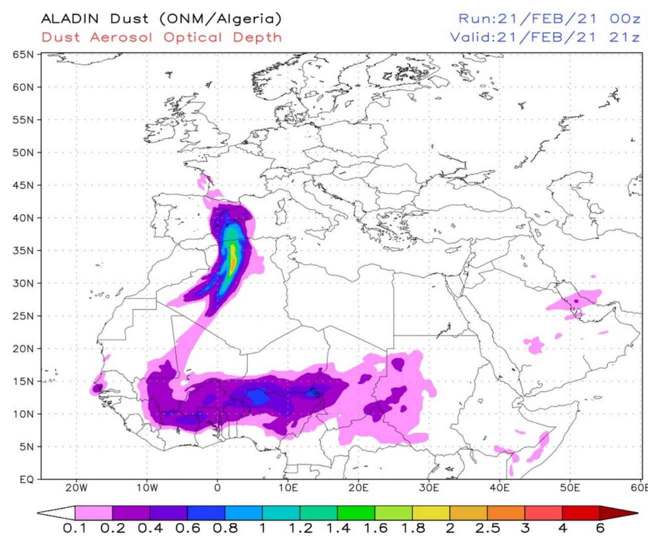

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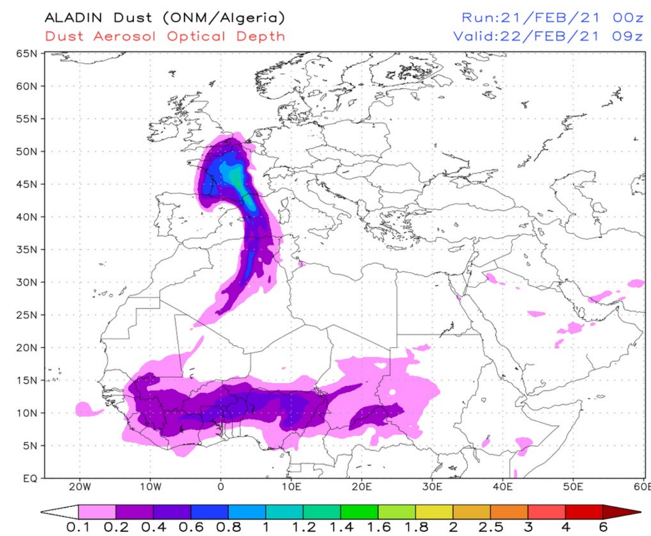

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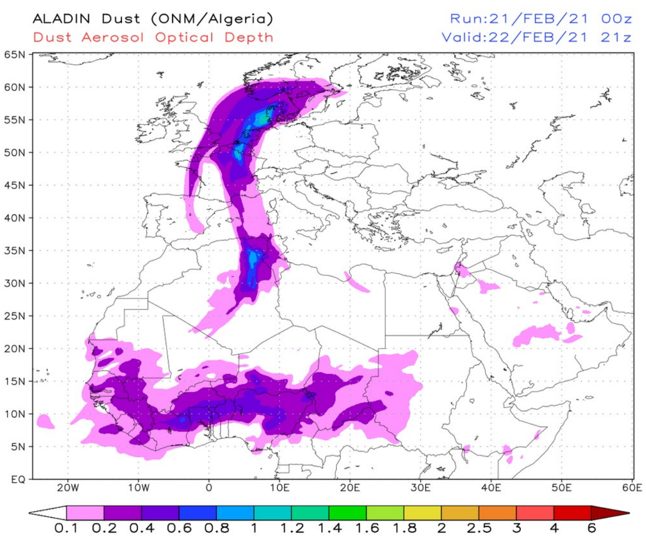

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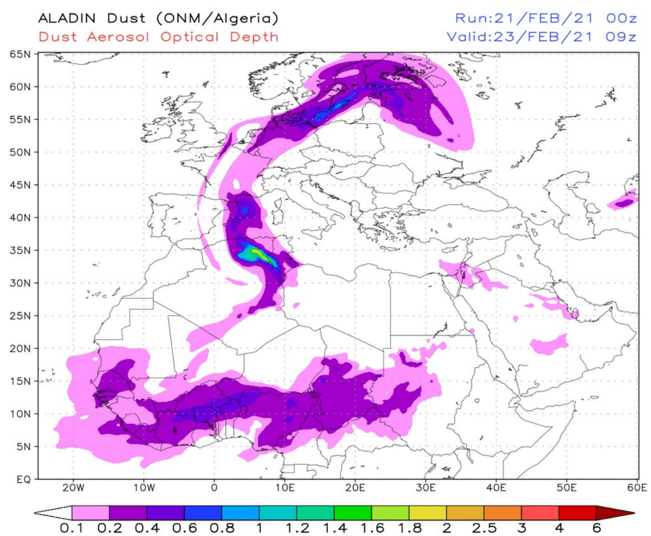

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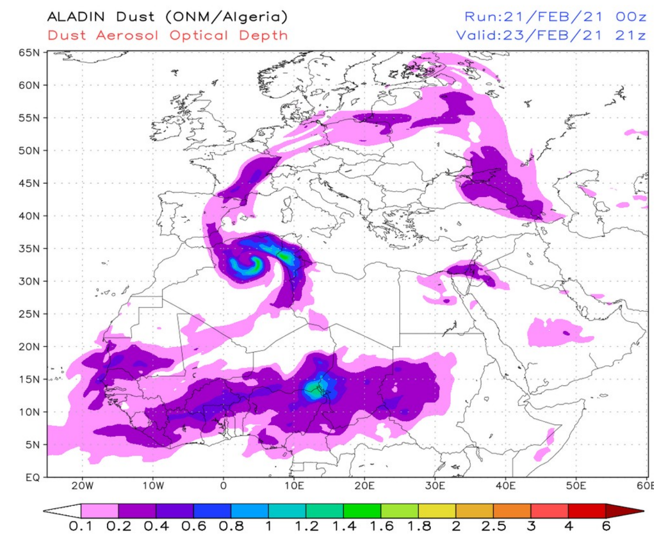

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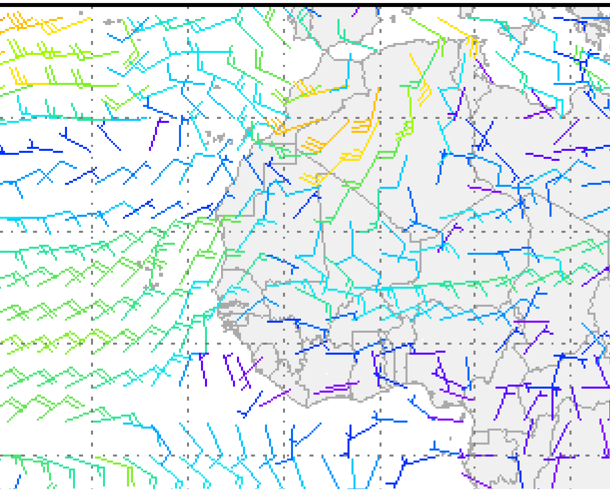
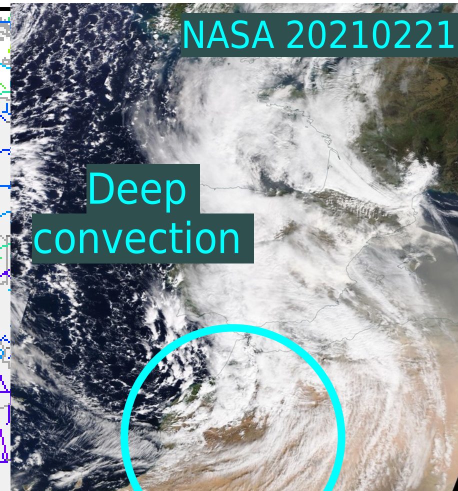
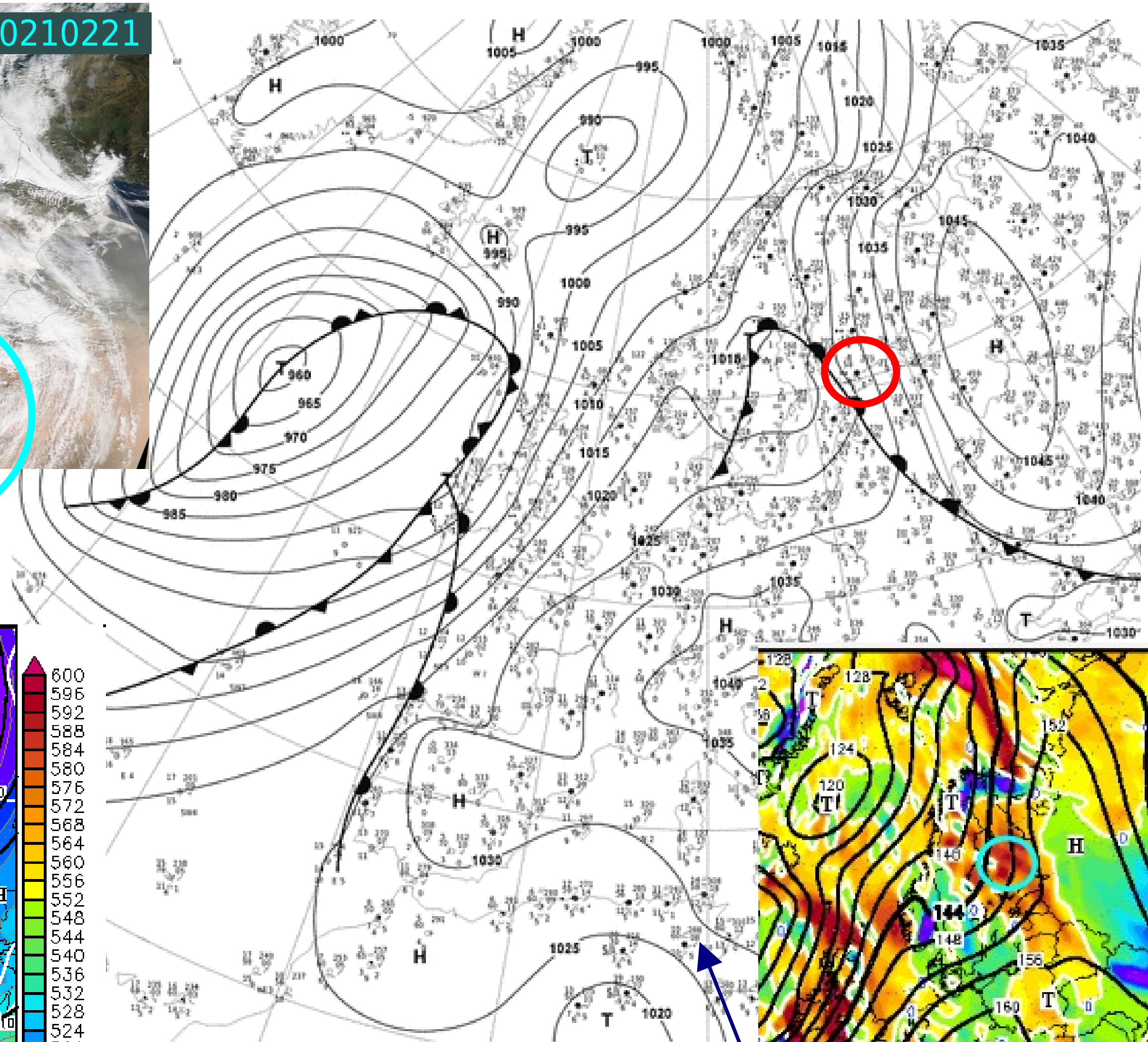
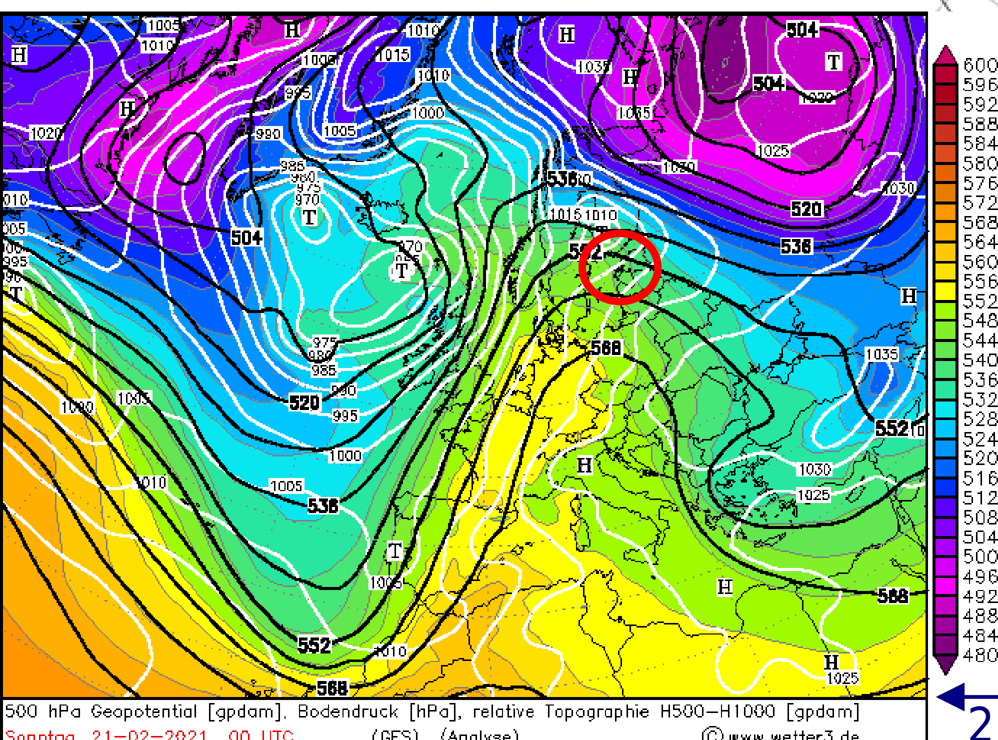
Weather maps for February 2021 Helsinki case





10-metre southwestern wind over Sahara
up to 15 m/s at 12UTC 20210221



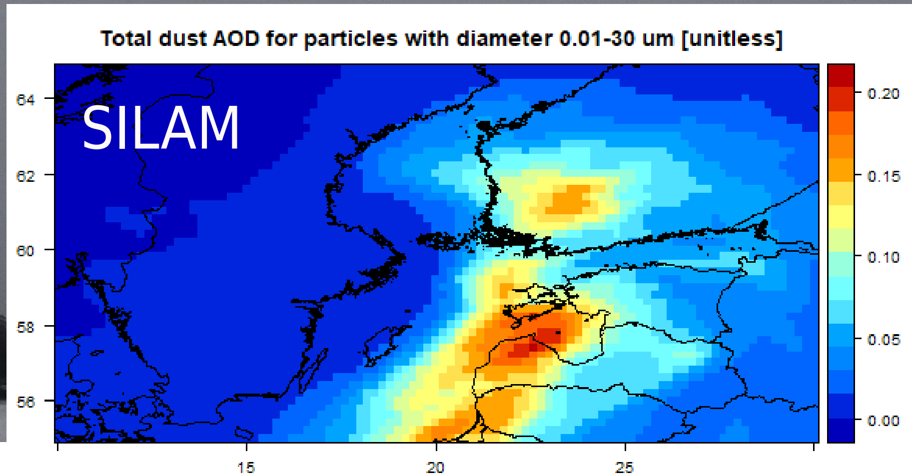


Strong southern flow:
z500, pmsl, rel.topo
1000-500hpa
21 February 2021 00UTC

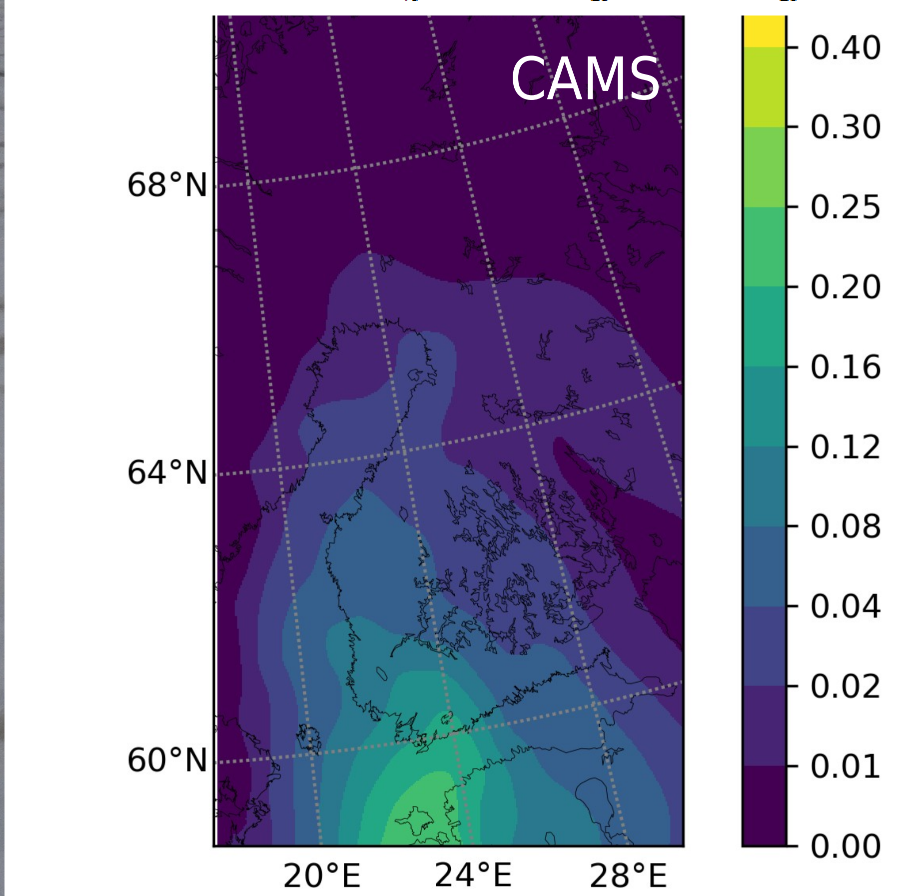
850 hpa geop., temp.adv.
23 February 2021 06UTC

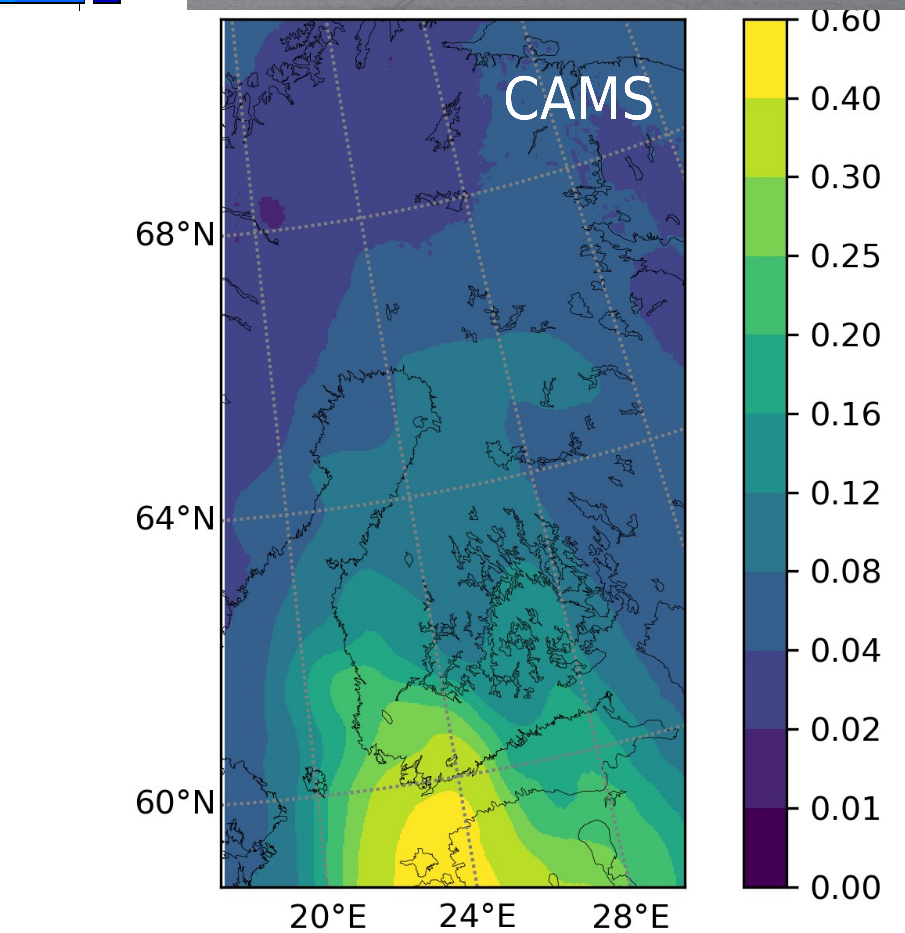
Data: GFS

09 UTC 23 February 2021
Saharan dust arrived in Finland

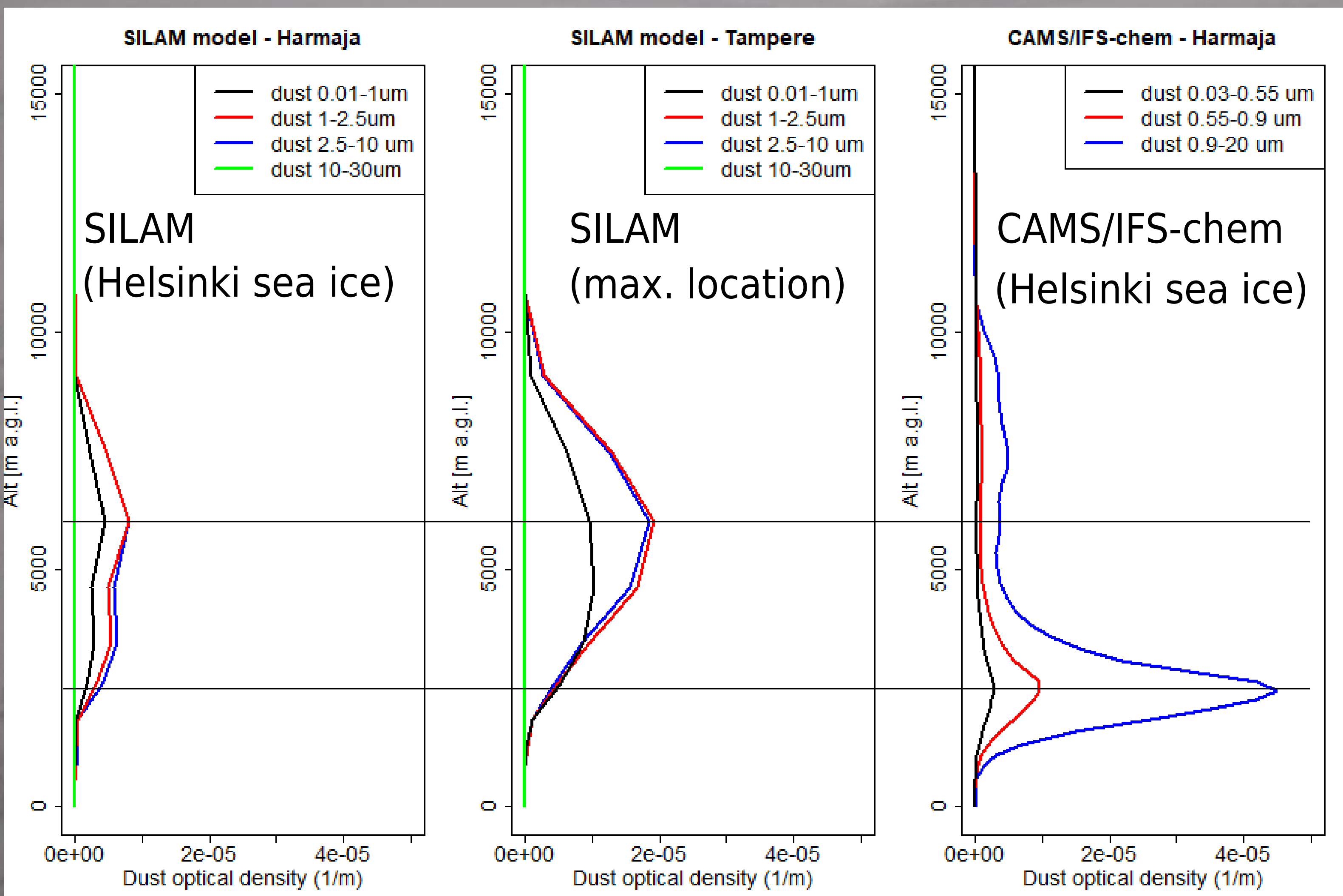


Dust total column optical depth at 550 nm [unitless] according to SILAM (left)



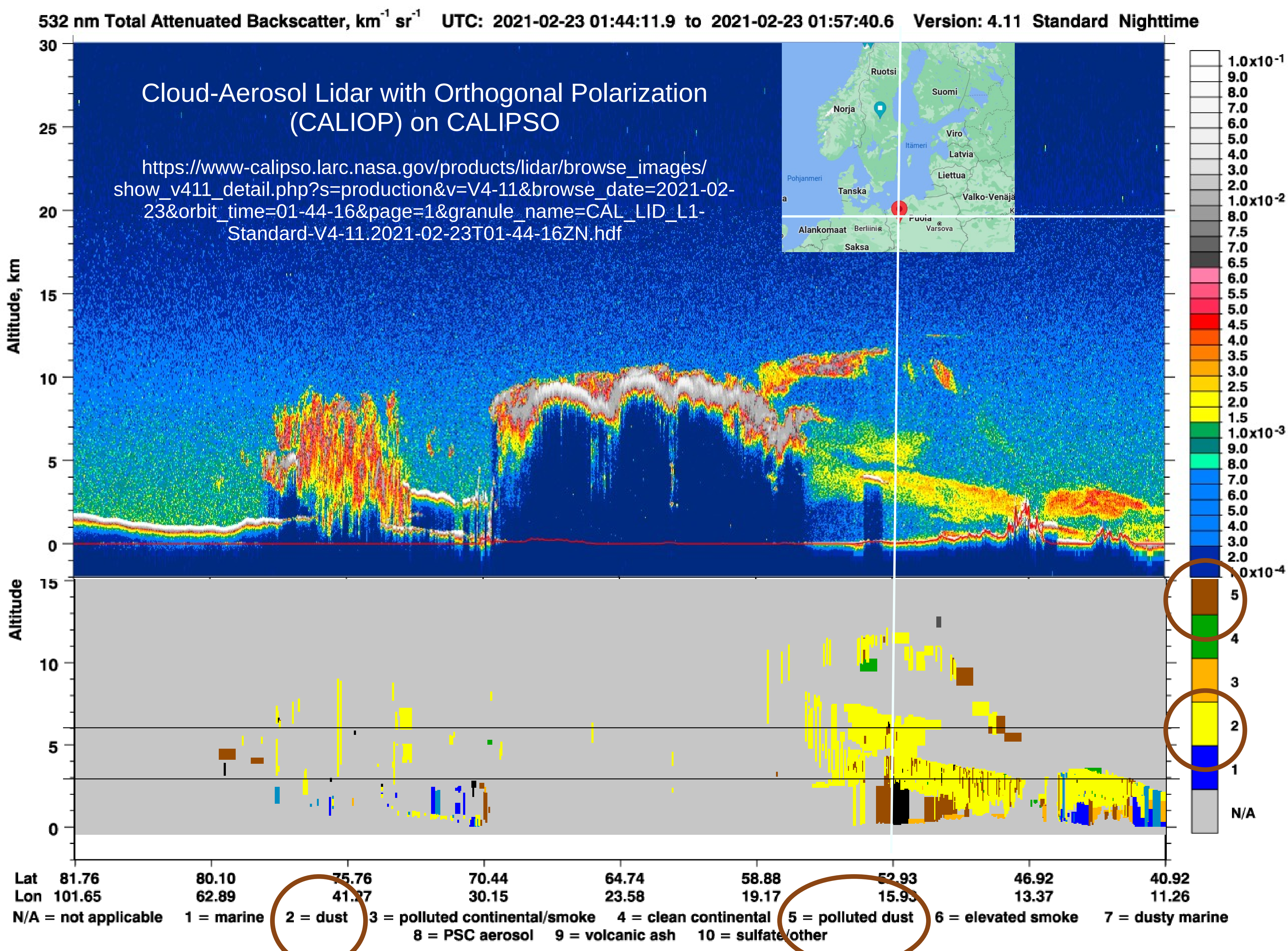


Aerosol total column optical depth at 550 nm according to CAMS/IFS-chem, dust particle sizes from 0.03 to 20 mkm (left) and all aerosols (right)



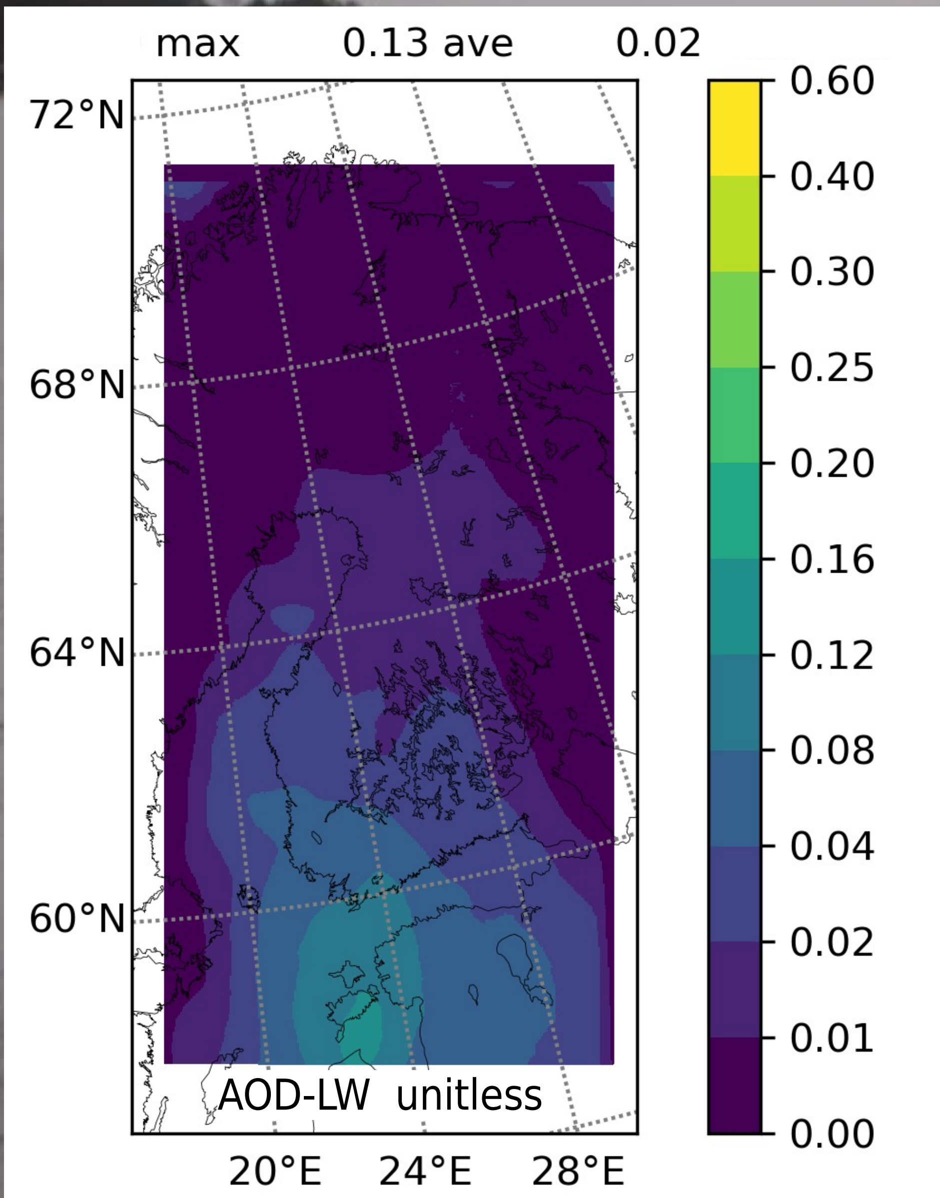
Vertical distribution of dust aerosol optical density [1/m] on 23 February 2021

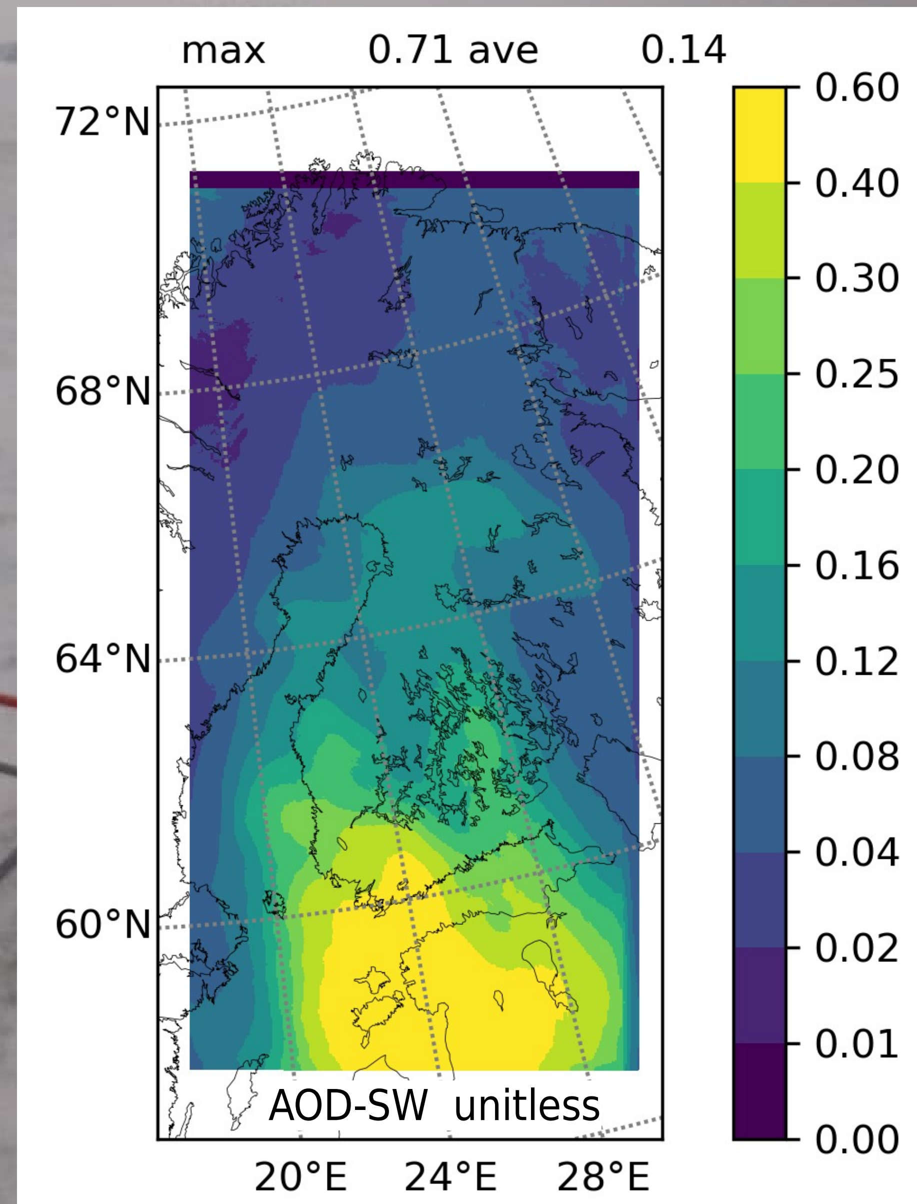
according to SILAM (left for Harmaja lighthouse, middle for Tampere) and CAMS (right for Harmaja)



532 nm Total Attenuated Backscatter, km-1 sr-1 UTC: 2021-02-23 01:44:11.9 to 2021-02-23 01:57:40.6 Version: 4.11 Standard Nighttime
Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on CALIPSO
https://www-calipso.larc.nasa.gov/products/lidar/browse_images/show_v411_detail.php?s=production&v=V4-11&browse_date=2021-02-23&orbit_time=01-44-16&page=1&granule_name=CAL_LID_L1-Standard-V4-11.2021-02-23T01-44-16ZN.hdf
Ruotsi
Suomi
Norja
Viro
Latvia
Liettua
Tanska
Valko-Venäjä
Alankomaat
Saksa
Altitude, km
Altitude
Lat 81.76 80.10 75.76 70.44 64.74 58.88 52.93 46.92 40.92
Lon 101.65 62.89 41.27 30.15 23.58 19.17 15.93 13.37 11.26
N/A = not applicable 1 = marine 2 = dust 3 = polluted continental/smoke 4 = clean continental 5 = polluted dust 6 = elevated smoke 7 = dusty marine
8 = PSC aerosol 9 = volcanic ash 10 = sulfate/other

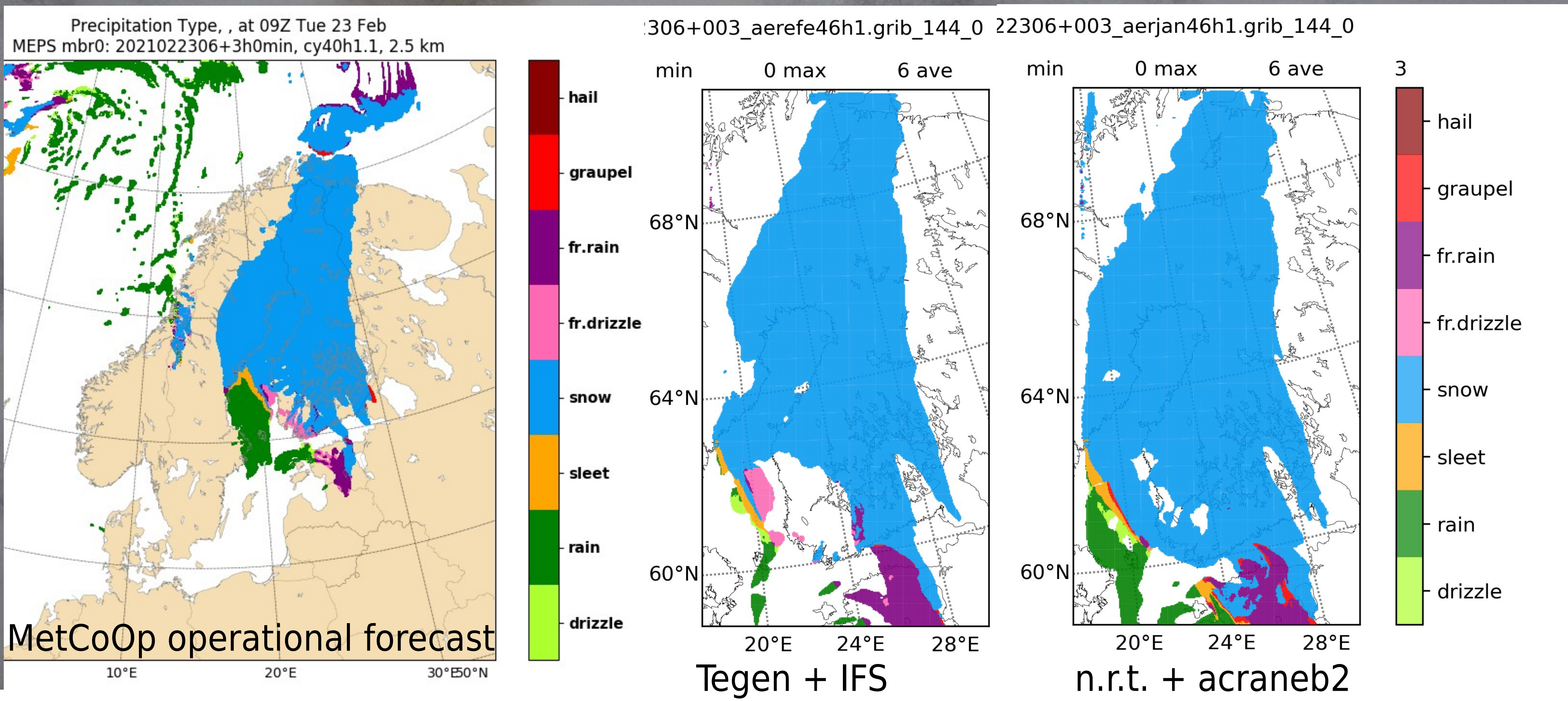
Total column optical depth of aerosol mixture over 16 LW (left) and 14 SW (right) spectral bands, derived from CAMS/IFS-chem in HARMONIE-AROME experiment. This can be used by acraneb and hlradia schemes for radiation calculations.



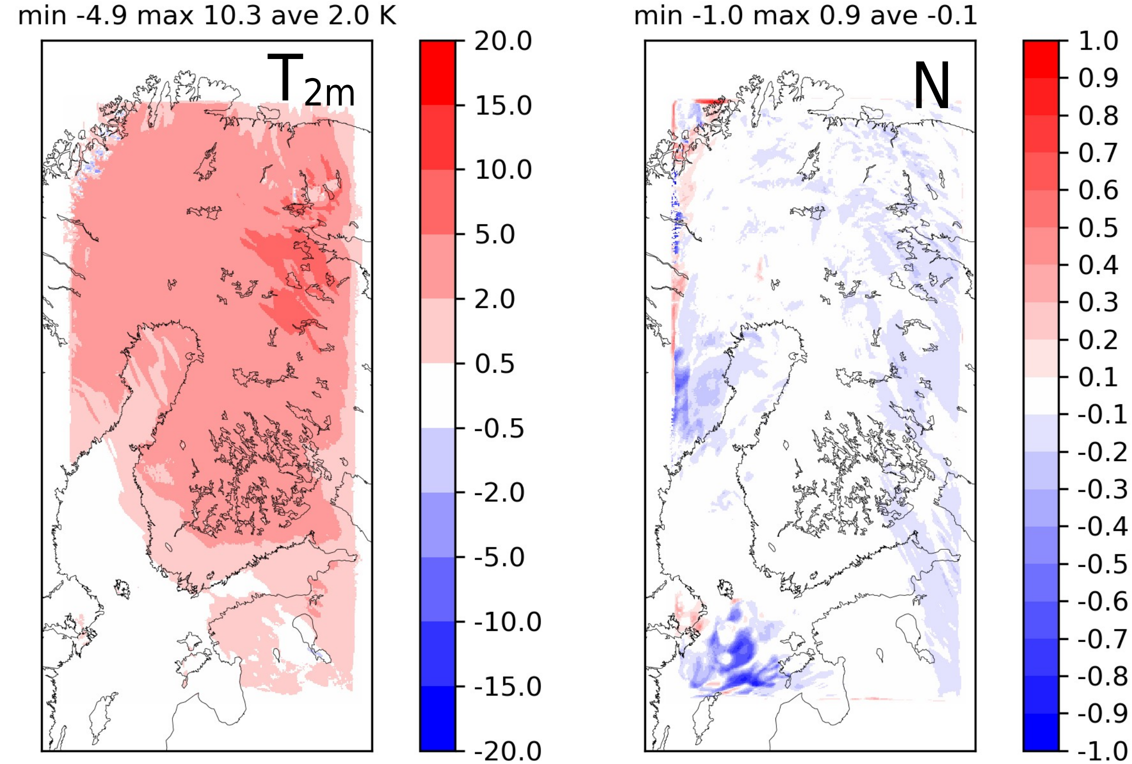


Comparisons on 23 Feb 2021 06 UTC+03h

Which variables to use as indicators?
What exactly is the reason of differences?
Introducing more complicated parametrizations and data – introducing more uncertainties and interactions

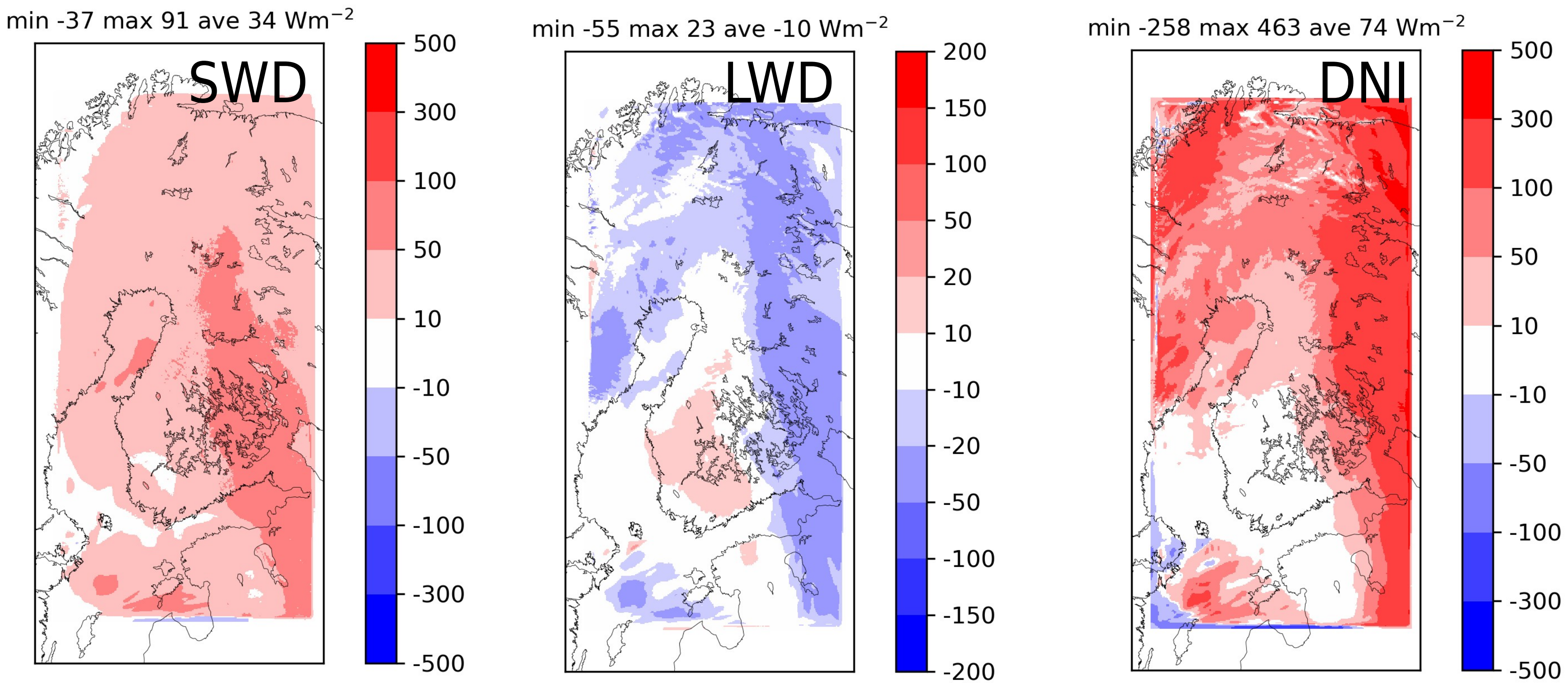


23 Feb 2021 06 UTC+03h



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

Detailed studies needed – MUSC as a tool for experimenting



MUSC is the single-column version of the ACCORD forecast model

We can modify the initial values of aerosols in air

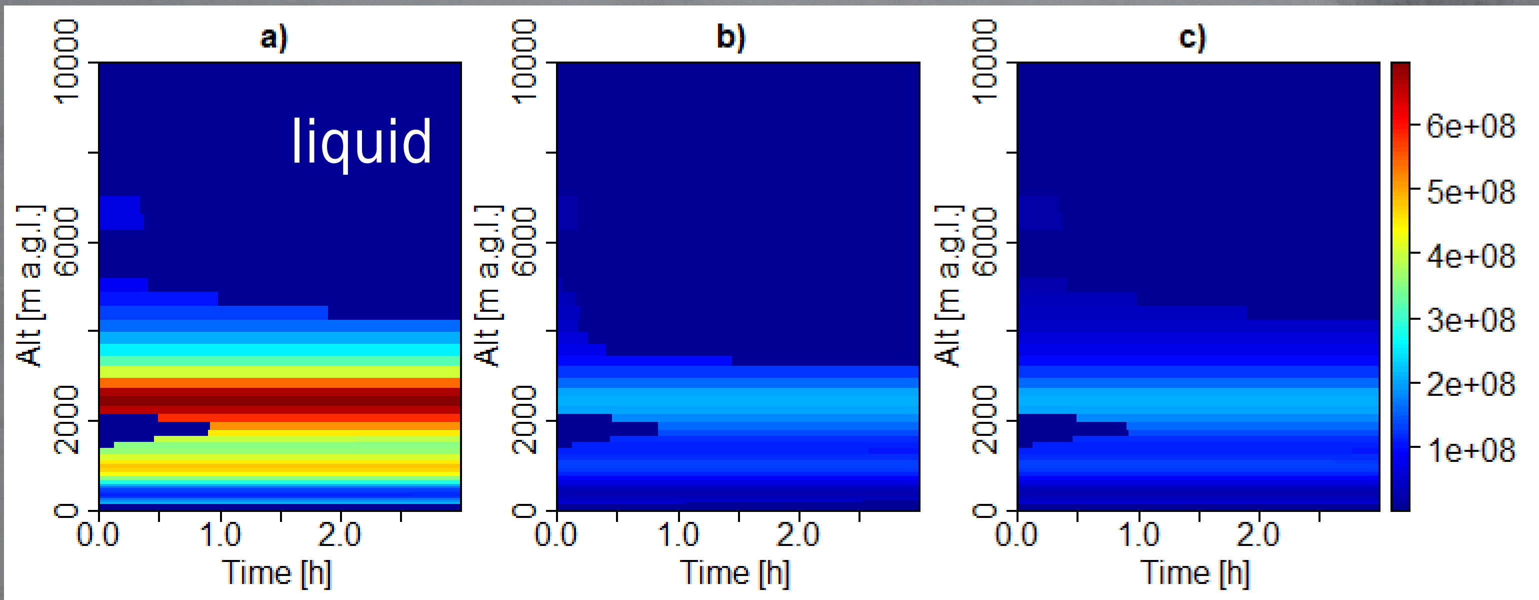
- climatological aerosol optical depth
- reanalysis-based aerosol mass mixing ratios
- near-real time mixing ratios
- no aerosols at all

We can play with radiation and cloud microphysics parametrizations

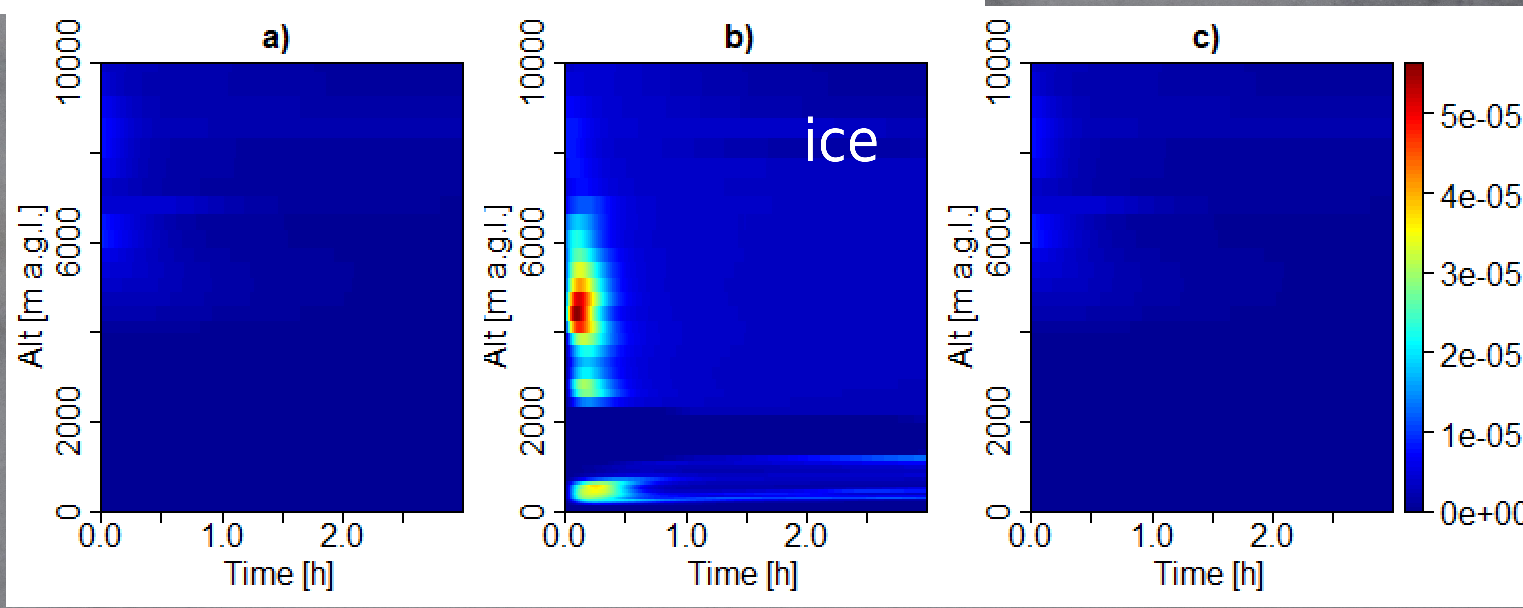
- different radiation schemes and options
- different microphysics schemes and options
- different ways to use aerosol data

We can learn about sensitivities and uncertainties but we cannot do real forecasts with MUSC

Example of MUSC sensitivity experiments on 23 February 2021. CAMS aerosols were used as input for different cloud microphysics parametrization options. MUSC was run for 3 hours from initial time.



Cloud condensation nuclei number concentration [1/m^3] for
a) configuration with increased value of supersaturation,
b) activated ice nuclei processes and
c) reference model configuration



Specific cloud ice content [kg/kg] for
a) configuration with increased value of supersaturation,
b) activated ice nuclei processes and
c) reference model configuration

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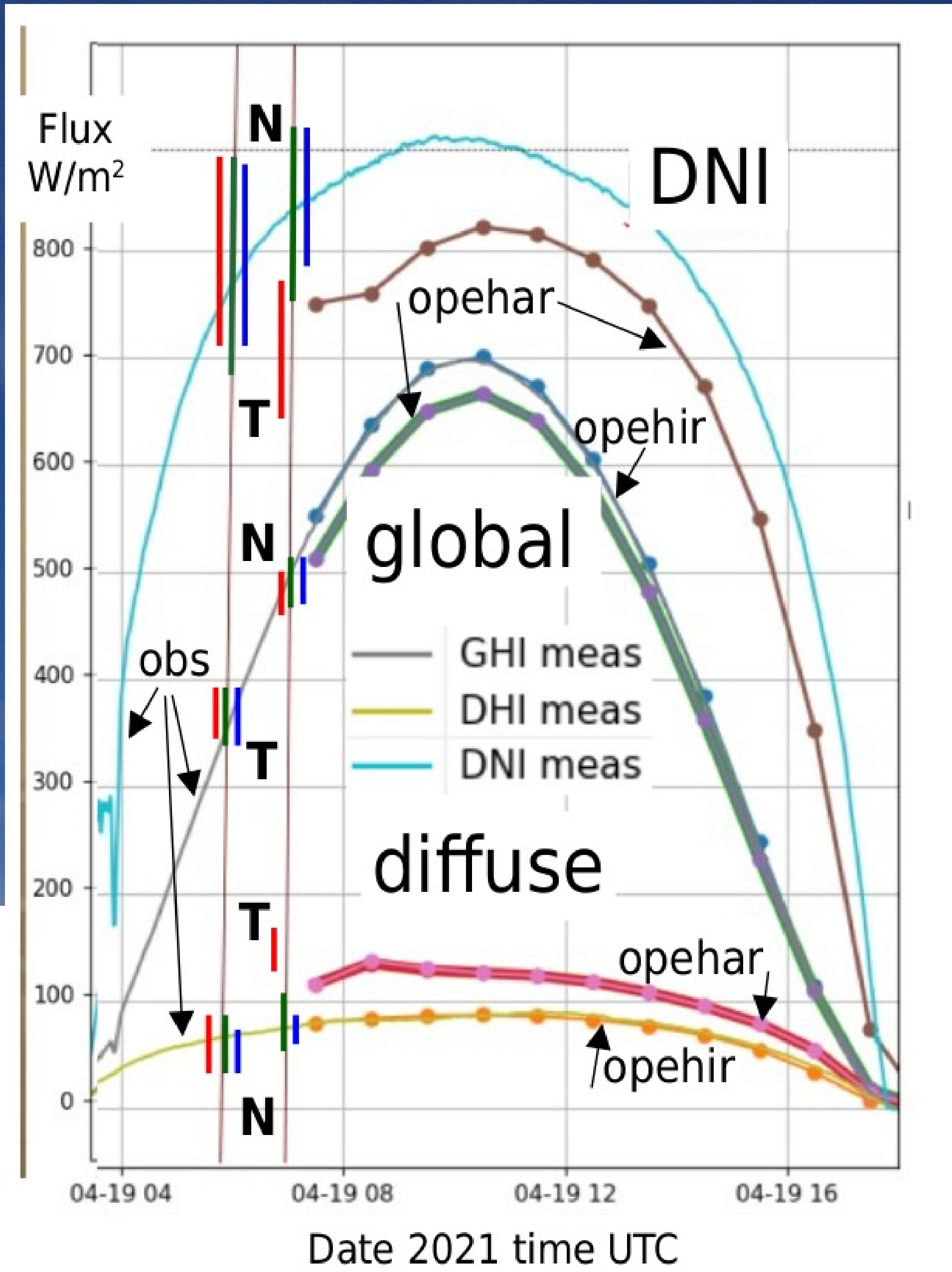
Helsinki 19th of April 2021 case represents clear and clean air conditions



Variables: DNI, GHI, DHI (diffuse!)
Observations (lines)
Operational Hirlam and MetCoOp Harmonie (lines with dots)

In operational Harmonie GHI and DNI seem to be underestimated and DHI overestimated

MUSC experiments
(vertical bars at 06 and 07 UTC)
Radiation schemes: IFS hlradia acraneb2
Aerosols: Tegen, clim. MMR, n.r.t. MMR, none

The largest DHI and smallest DNI are given by all radiation schemes when AOD550 (**T**) is used. Differences in global radiation are smaller between the different radiation schemes and assumed aerosol sources.

Side comment on
global, direct, diffuse, direct normal irradiance

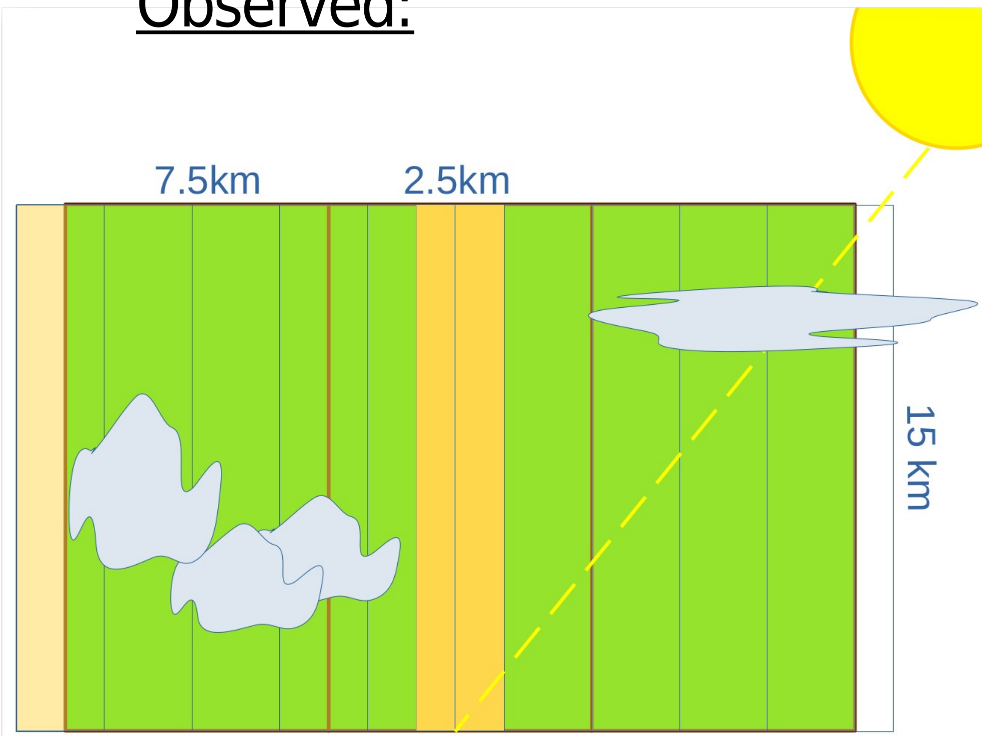
<u>In the model:</u>

Global radiation (GHI) at the surface is calculated in the atmospheric column above. It is the primary output variable of any radiation scheme.

Direct and diffuse (DHI) at the surface are derived diagnostically taking into account clouds and aerosols.

Direct normal irradiance (DNI) in the model is approximated by dividing direct irradiance by the cosine of solar zenith angle.

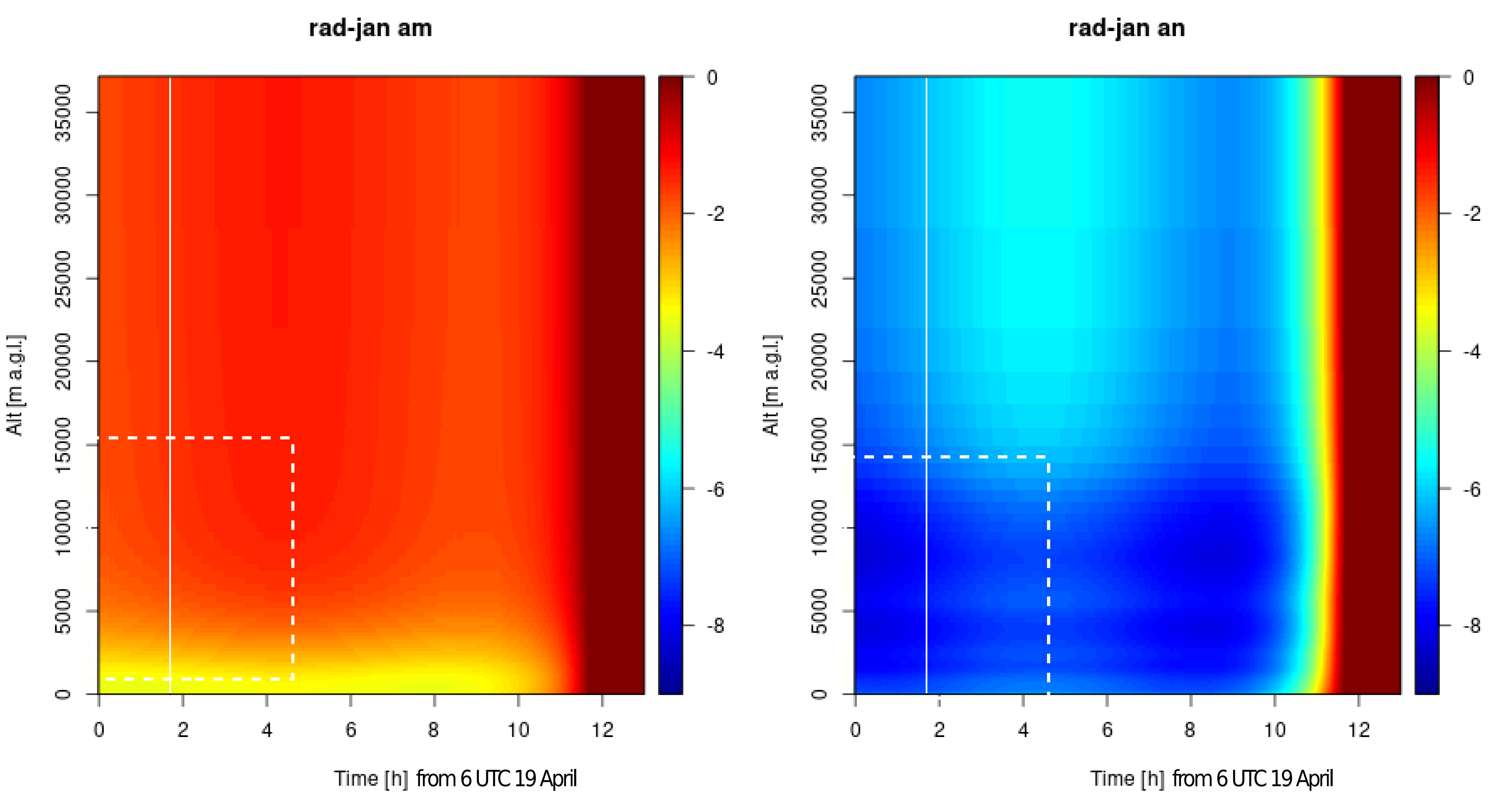
<u>Observed:</u>



Observed DNI is a result of a point measurement by an instrument following sun.

It differs by definition from its model counterpart!

acraneb2 and hlradia are able to use aerosol optical properties, derived for the mixture of 11 CAMS aerosol species and applied to n.r.t. or climatological MMRs, taking into account run-time humidity and averaging over SW and LW parts of the spectrum



Difference between AOD550-based and MMR-based aerosol optics in acraneb2: net SW radiation flux by the new optics (jan) is larger than those by old optics (rad) by up to 10 Wm^{-2} when climatological (am) and n.r.t. (an) MMRs are used in the 19th April 2021 case when observed aerosol loads were small.

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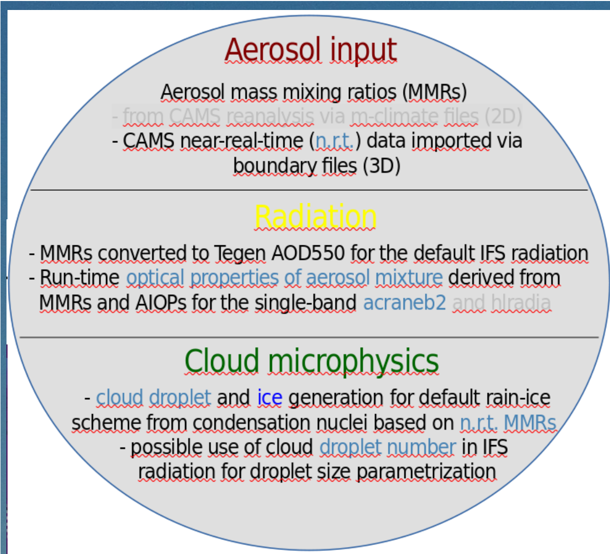
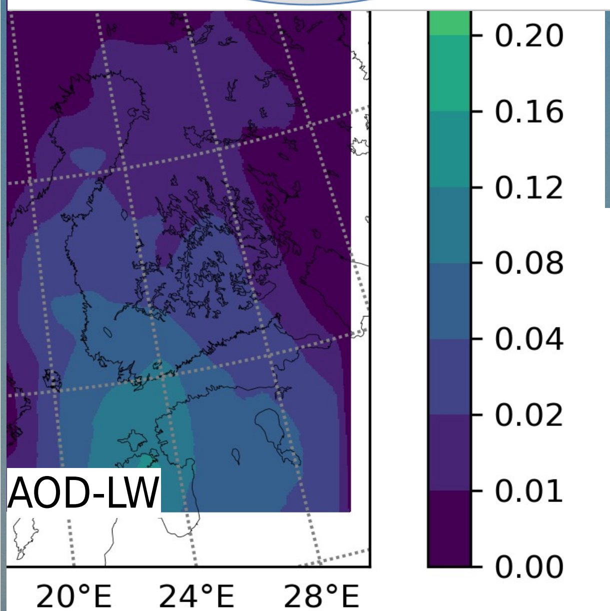
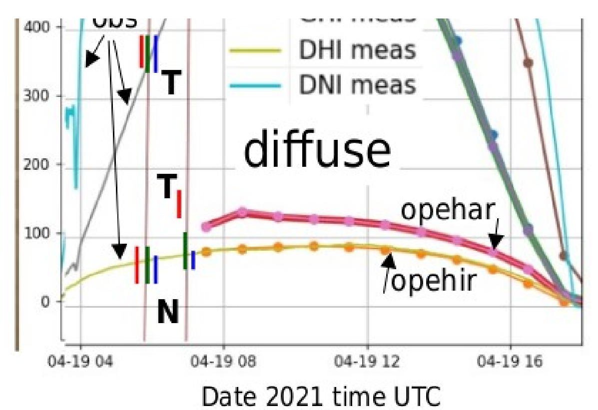






Concluding remarks

There is research code with climatological and n.r.t. aerosol MMRs + advanced optical properties for 3 radiation schemes. Impacts of n.r.t aerosol in cloud/precipitation microphysics within ice3/ocnd have been parametrized. CAMS n.r.t. and climatological MMR data and IOPs can be introduced to experiments within cy43h and cy46h.

MUSC and full model experiments have been run, preliminary results obtained. Sensitivies, interactions and differences are seen, further studies are needed to shed light to open questions. Extended diagnostic variables are needed to understand the impacts in 3D and MUSC experiments.

Unification of all code and tools into the framework of cy46t has been started according to the RWP task PH6. Extensive testing, improvements, development will be possible after that, leading to understanding what of CAR would be needed for operational applications.

THANK YOU – DISCUSSION, QUESTIONS!

Clean air in Salla, Finnish Lapland 31.3.2022. Photo: Laura Rontu

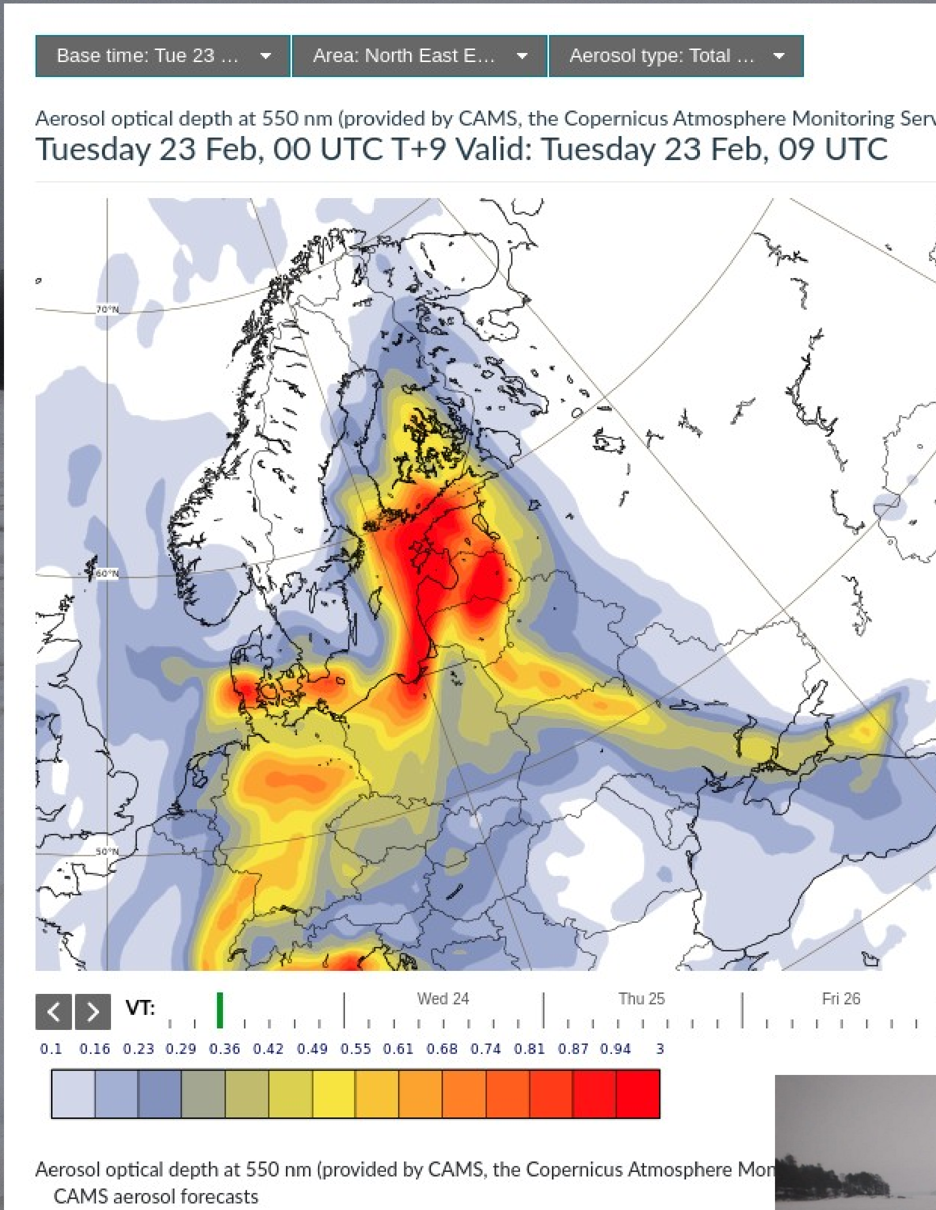
Aerosols and weather

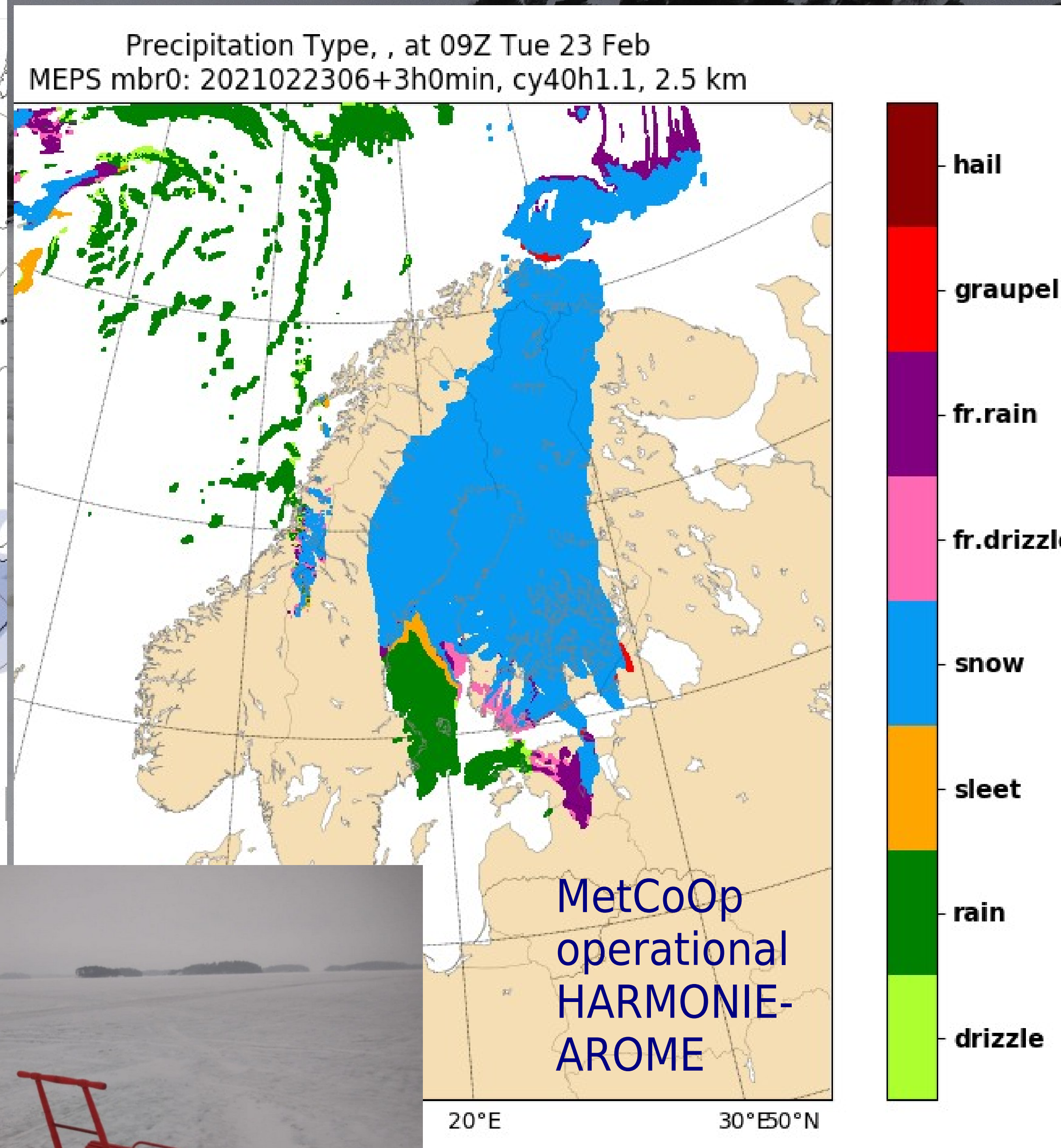
In clear-sky cases, the global SW radiation at the surface may reduce tens of W/m^2 due to direct radiation impact of aerosol. Influence of dust on visible and near-infrared solar radiation can be significant.

Atmospheric aerosols influence the evolution of clouds, precipitation and fog.
Dust particles are insoluble, thus they influence in formation of cloud ice.

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

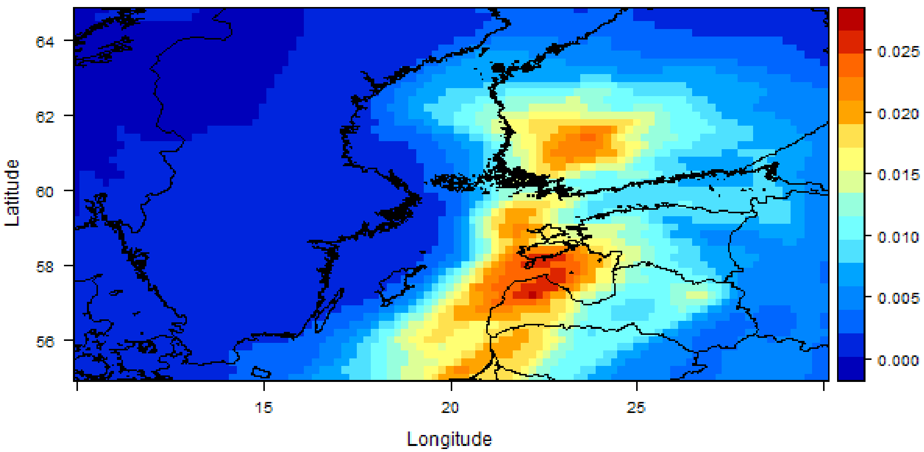
20210223 09UTC



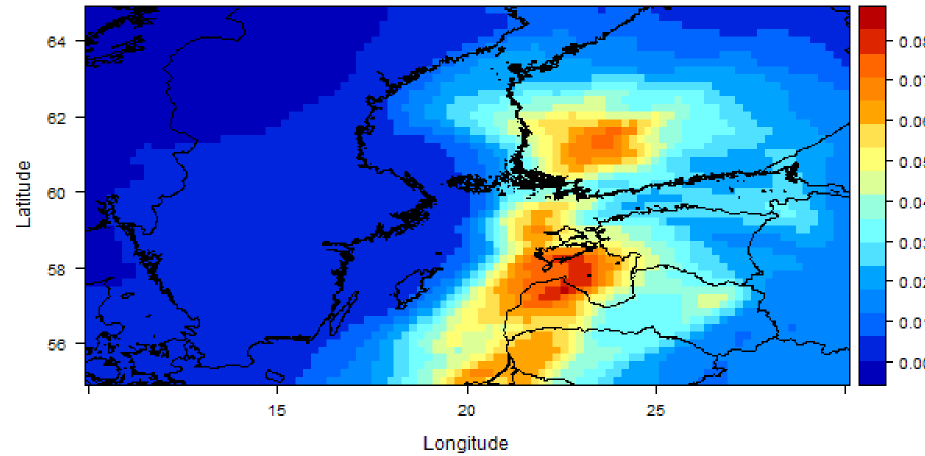


Total AOD@550nm
https://atmosphere.copernicus.eu/charts/cams/aerosol-forecasts

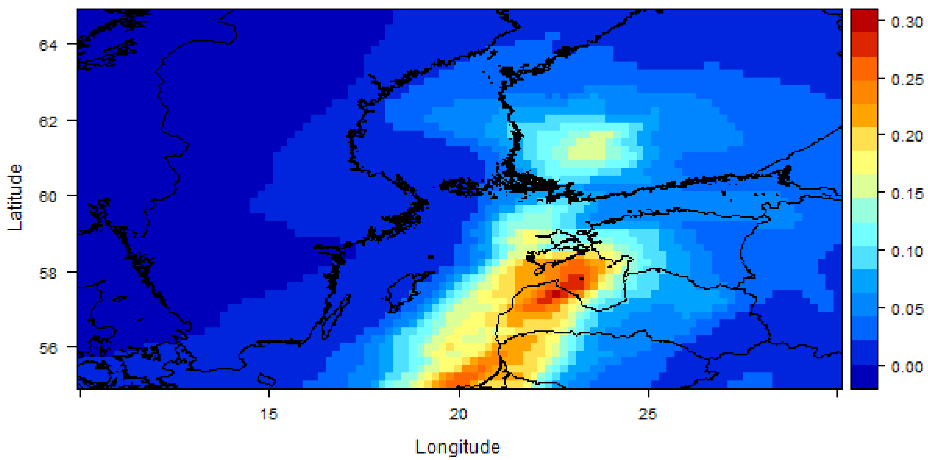
Dust concentration in total column for particles with diameter 0.01-1um [g/m2]



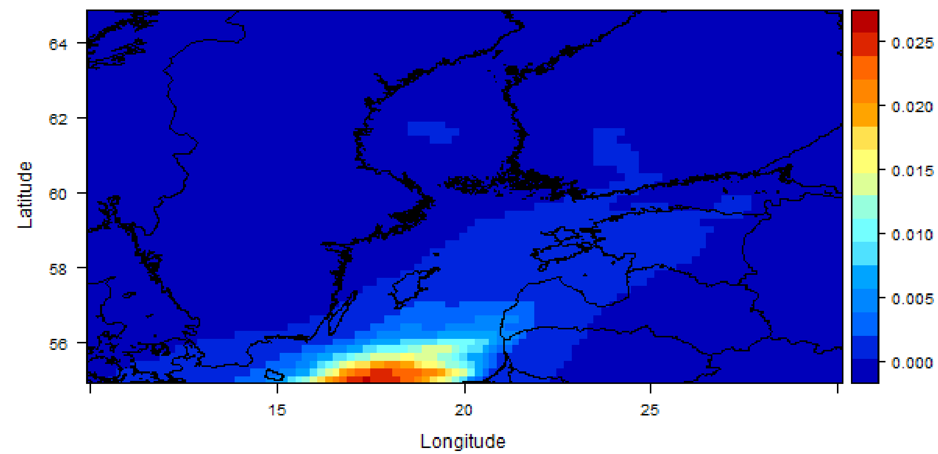
Dust concentration in total column for particles with diameter 1-2.5um [g/m2]



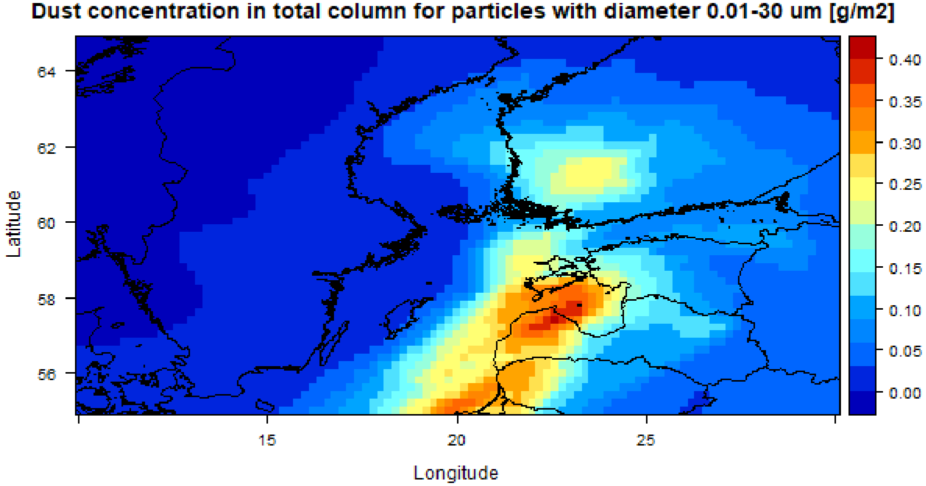
Dust concentration in total column for particles with diameter 2.5-10um [g/m2]



Dust concentration in total column for particles with diameter 10-30um [g/m2]



Dust concentration in total column for particles with diameter 0.01-30 um [g/m2]

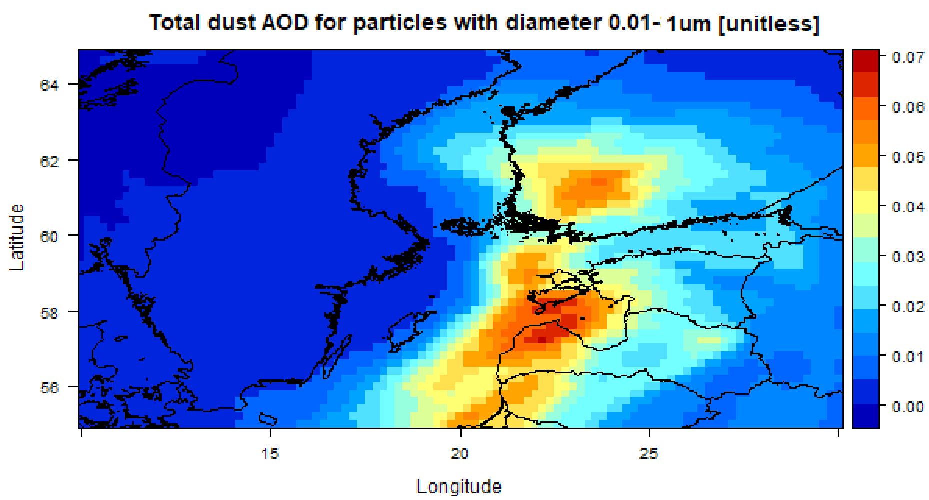


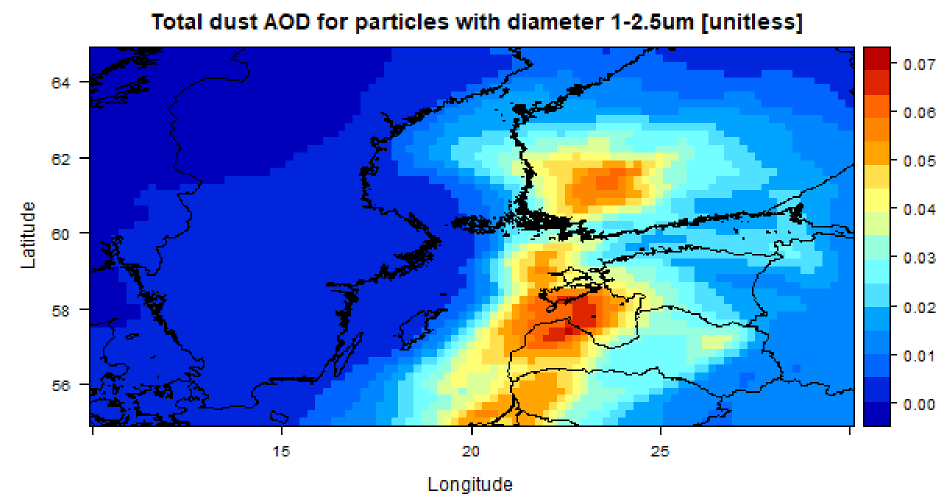
Result of SILAM (https://silam.fmi.fi) dust simulation experiment for 09 UTC on 23 February 2021

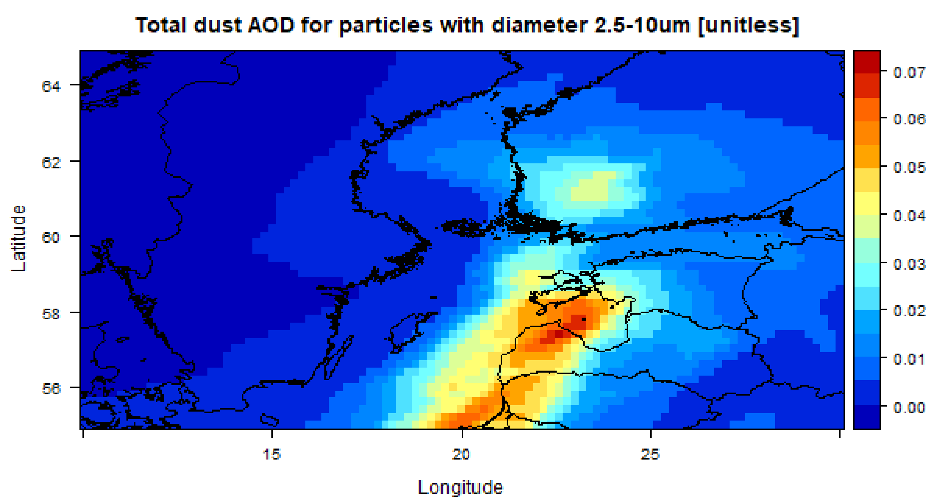
Total-column mass of dust aerosol [g/m^2] of four size classes and their sum. The maximum dust load over Helsinki sea ice was around 0.15 g/m^2 , over Tampere 0.25 g/m^2

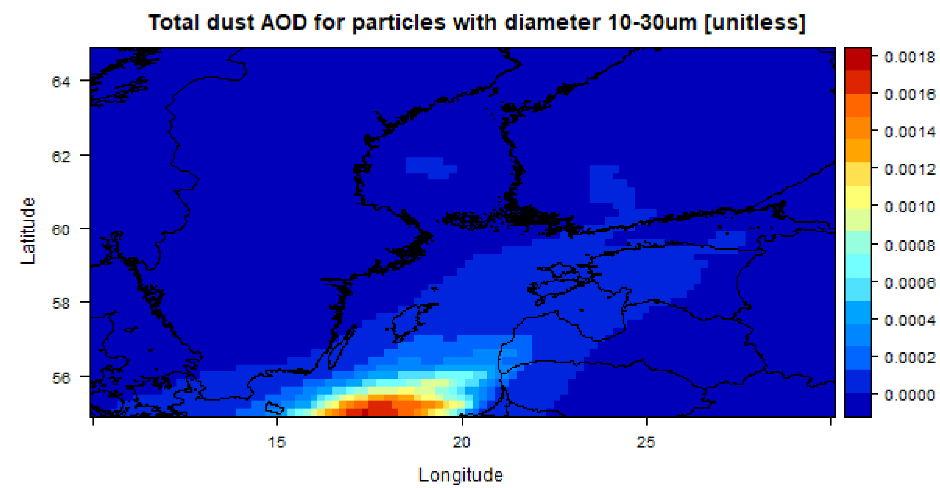
Result of SILAM (https://silam.fmi.fi) dust simulation experiment

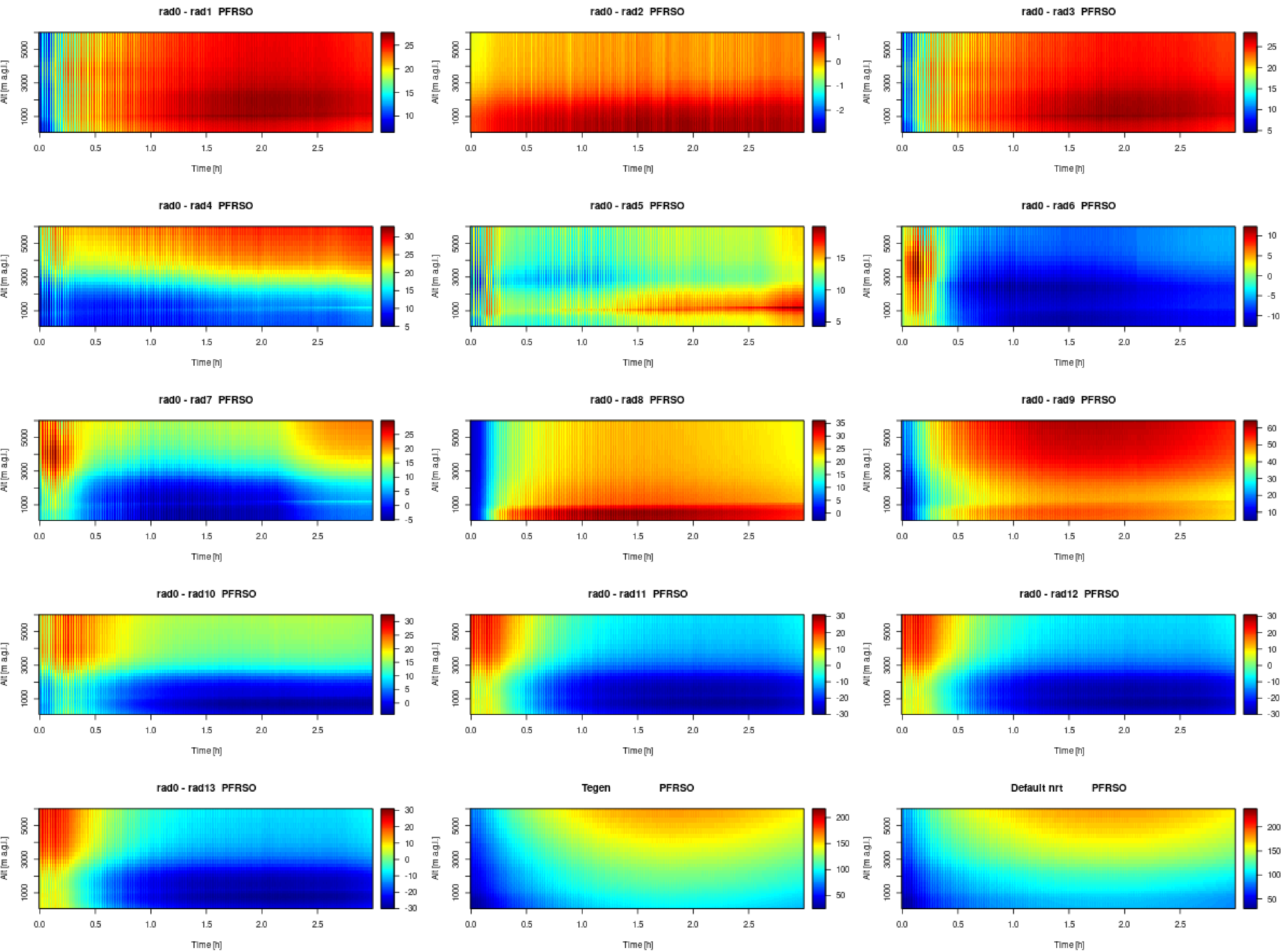
Dust aerosol total-column optical depth for 09 UTC on 23 February 2021





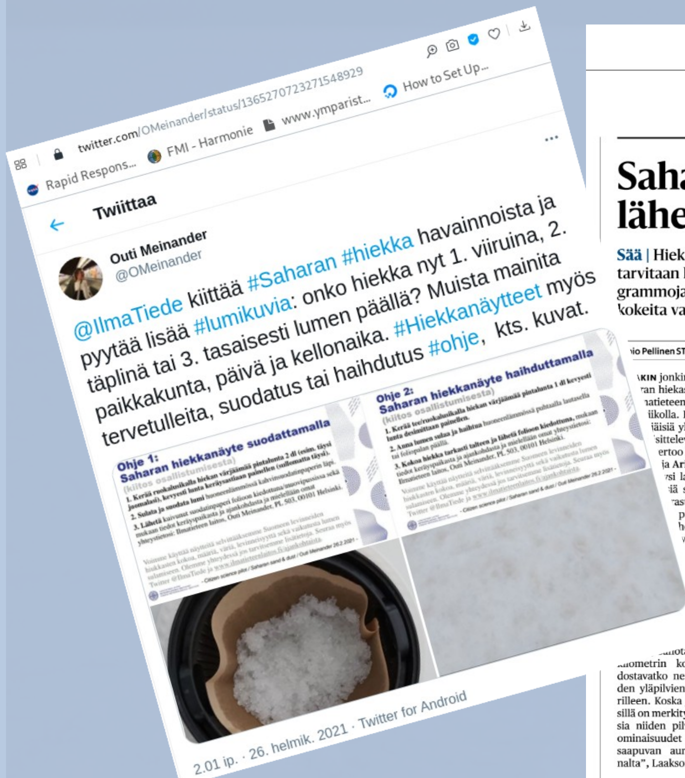




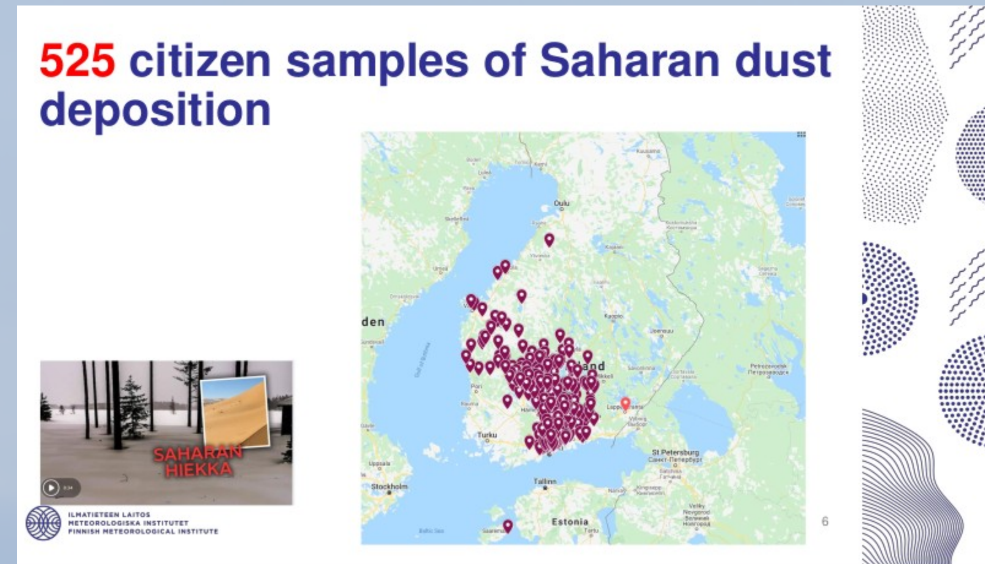


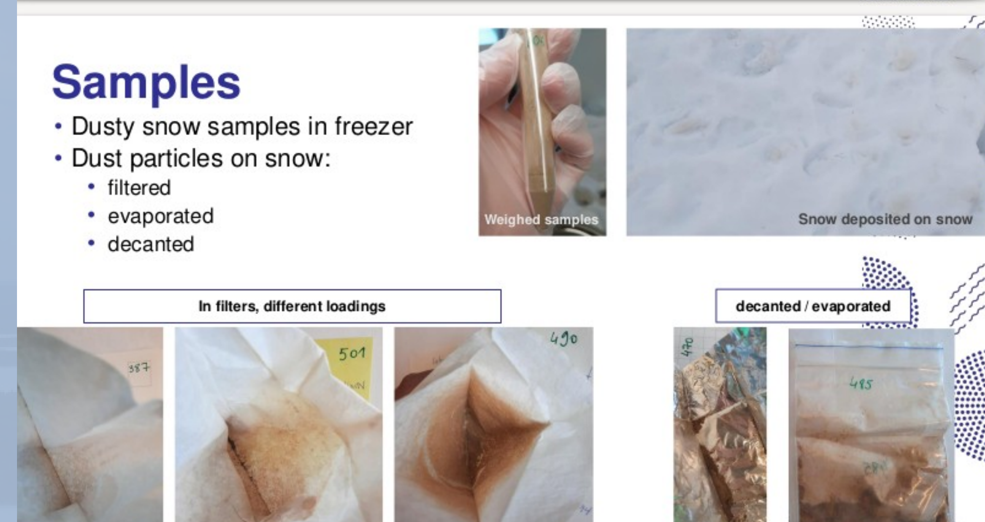
rad0 - rad1 PFRSO
rad0 - rad2 PFRSO
rad0 - rad3 PFRSO
rad0 - rad4 PFRSO
rad0 - rad5 PFRSO
rad0 - rad6 PFRSO
rad0 - rad7 PFRSO
rad0 - rad8 PFRSO
rad0 - rad9 PFRSO
rad0 - rad10 PFRSO
rad0 - rad11 PFRSO
rad0 - rad12 PFRSO
rad0 - rad13 PFRSO
Tegen PFRSO
Default nrt PFRSO
Alt [m a.g.l.]
1000
3000
5000
Time [h]
0.0
0.5
1.0
1.5
2.0
2.5

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.