emep

Co–operative programme for monitoring and evaluation of the long–range transmissions of air pollutants in Europe

UNECE

Convention on Long-range Transboundary Air Pollution

LRTAP
Long-range Transboundary Air Pollution

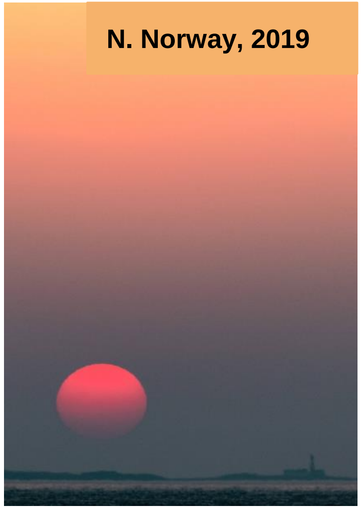
Natural PM contribution with EMEP MSC-W model:

Status & challenges

Svetlana Tsyro, Daniel Heinesen, Hilde Fagerli & colleagues from the EMEP/MSC-W team

Norwegian Meteorological Institute

27th TFMM meeting, Bled, Slovenia, 28-29 April 2026



Outline

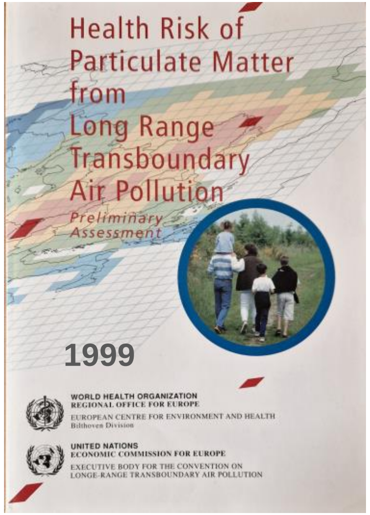
Natural dust is in focus of this presentation

Status:

- Model results for dust contribution to PM
- Evaluation/verification options
- Identified issues

Reflections on:

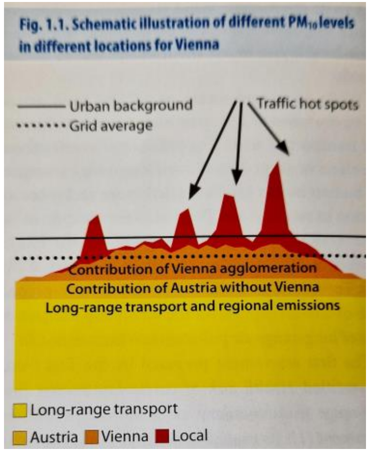
- Challenges for improvements
- Ways forward



PM_{10} & $PM_{2.5}$:

- ➔ cause adverse **health effects** (epidemiological studies)
- ➔ can be **attributed to long-range transboundary** air pollution (can have particularly large role in populated areas with no heavily polluting local emissions)
- ➔ uncertainty wrt how much PM chemical composition may be relevant to the health effects (recend indication of **dust contribution to oxidative potential**)

WHO, 2006



==> Accounting for all PM components (from anthropogenic and natural sources) in models is essential for **accurate assessments of regional BG PM_{10}/$PM_{2.5}$**

==> Natural PM (dust, sea salt) are not only necessary for **PM mass closure**, but also for sound description of heterogeneous chemistry (gas/aerosol partitioning)

Under Article 16 of the **revised EU AAQD** Member states are allowed to identify/subtract **natural contributions** when **exceedances** of air quality limit values occur.

… contributions from **natural sources shall be deducted** before calculating the **average exposure indicator** (AEI = 3-calendar-year running annual mean concentration)

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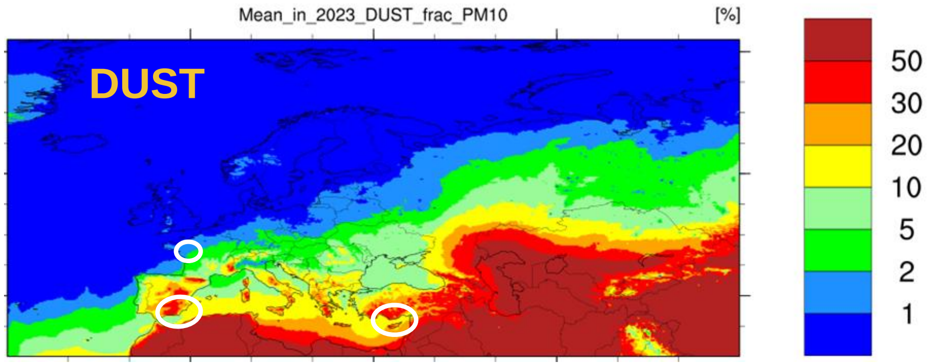
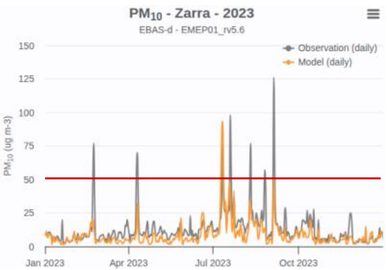
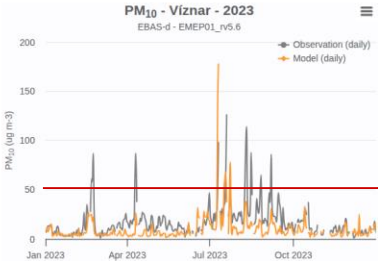
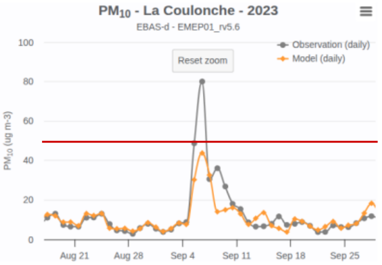
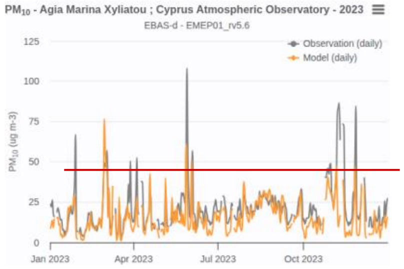
Natural contributions to annual mean PM_{10} and daily PM_{10} exceedances (of 50 ug/m^3)

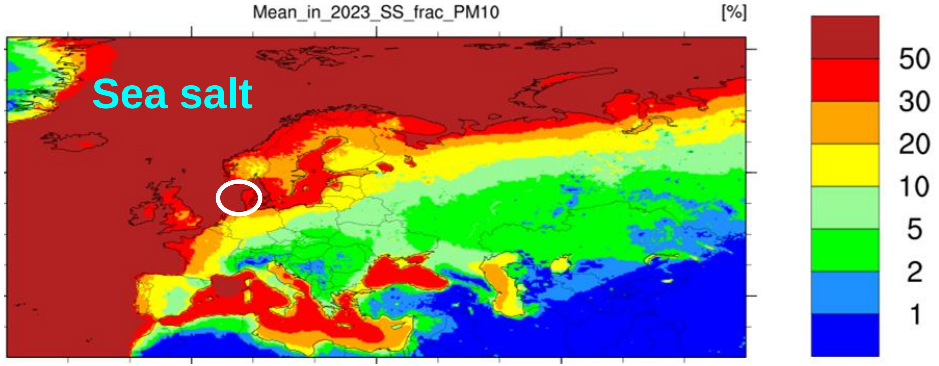


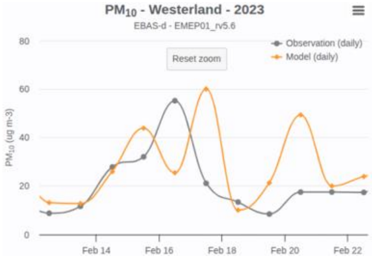


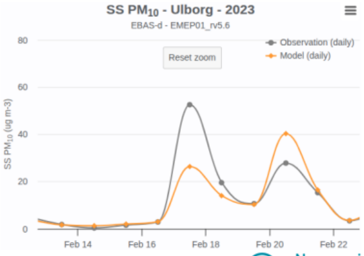












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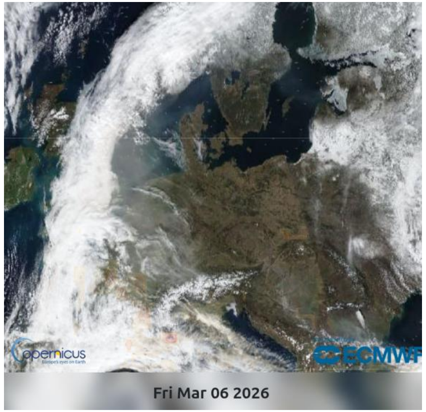
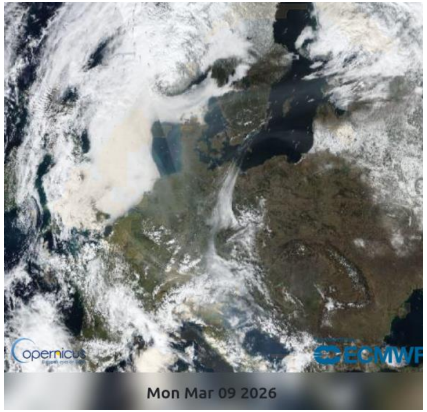
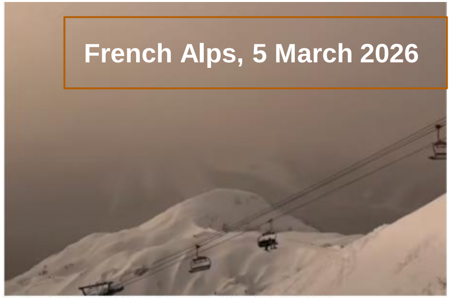
EMEP forecasting of PM episodes within CAMS Policy Support:

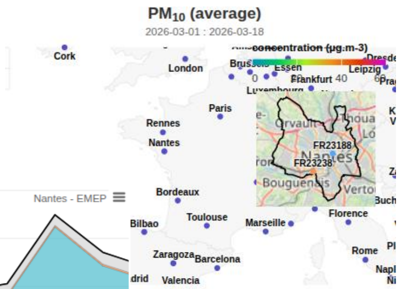
Saharan dust event beginning of March 2026

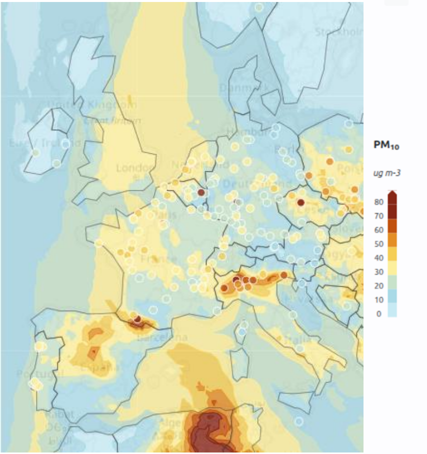


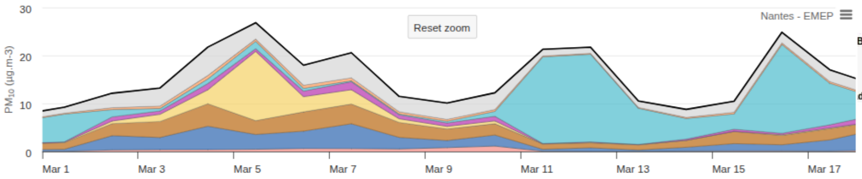


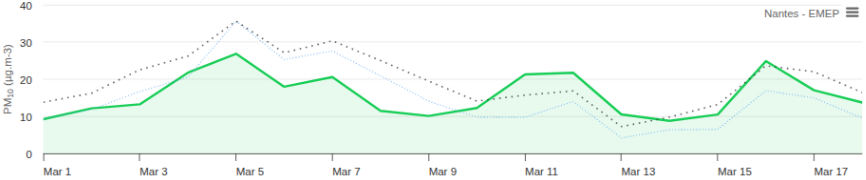


En Savoie, les Alpes ressemblent à d'incroyables paysages lunaires, jeudi 5 mars 2026. (©DR)









Nantes, FR

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Dust emissions scheme - plenty (semi-)empirical formulas & parameters (*Marticorena&Bergametti, Alfaro, Gomes,...)*

Threshold friction velocity

$$u_{*,\mathrm{th}} = \frac{u_{*,\mathrm{sm}}}{f_{\mathrm{eff}}} f_w$$

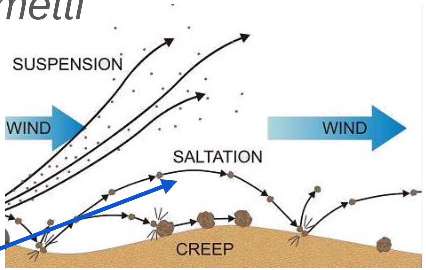
$$f_{\mathrm{eff}} = 1 - \left(\frac{\ln\left(\frac{z_0}{z_{0,s}}\right)}{\ln\left(0.35\left(\frac{10}{z_{0,s}}\right)^{0.8}\right)} \right)$$

$$f_w = \sqrt{\left(1 + 121\,(w - w')^{0.68}\right)}$$

$$w = 0.14\,F_{\mathrm{clay}}^2 + 0.17\,F_{\mathrm{clay}}$$

Mortecorena&Bergometti

$$\boxed{u_* \geq u_{*,\mathrm{th}}.}$$



Model assumptions:
Erodible soils - deserts & arable lands
36-42 h after rain (soil crust)
Dust Flux is injected in the lowest layer
Ca. 50% - in PM10
Distributed btw fine/coarse dust PM

$$Q_s = \frac{C\rho_{\mathrm{air}}}{g} u_*^3 \left(1 - \frac{u_{*,\mathrm{th}}}{u_*}\right)\left(1 + \frac{u_{*,\mathrm{th}}}{u_*}\right)^2$$

$$\boxed{F = A_s\, K\, \alpha\, Q_s}$$

$$a = 10^{0.134\,(\%\ \mathrm{clay}) - 6}$$

C = 2.16 (Zender et al. 2003)

K - soil erodibility

α - sandblasting efficiency

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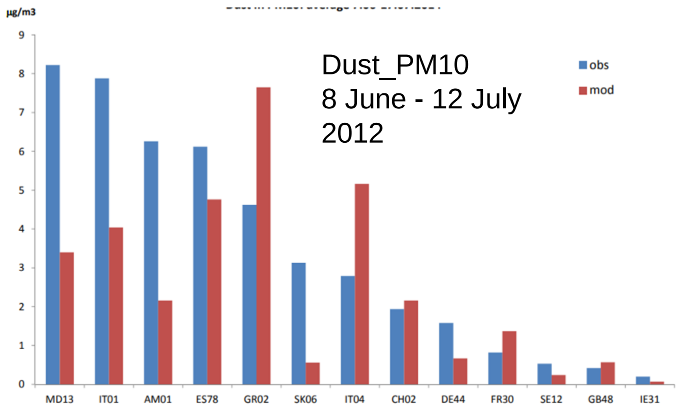
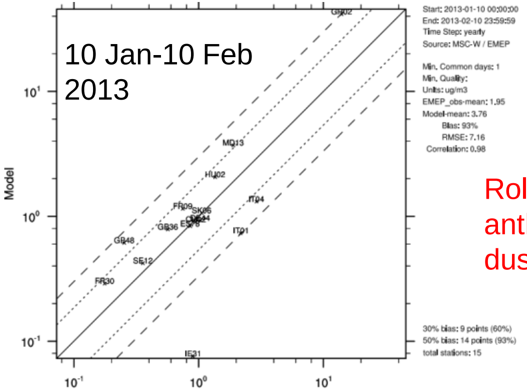
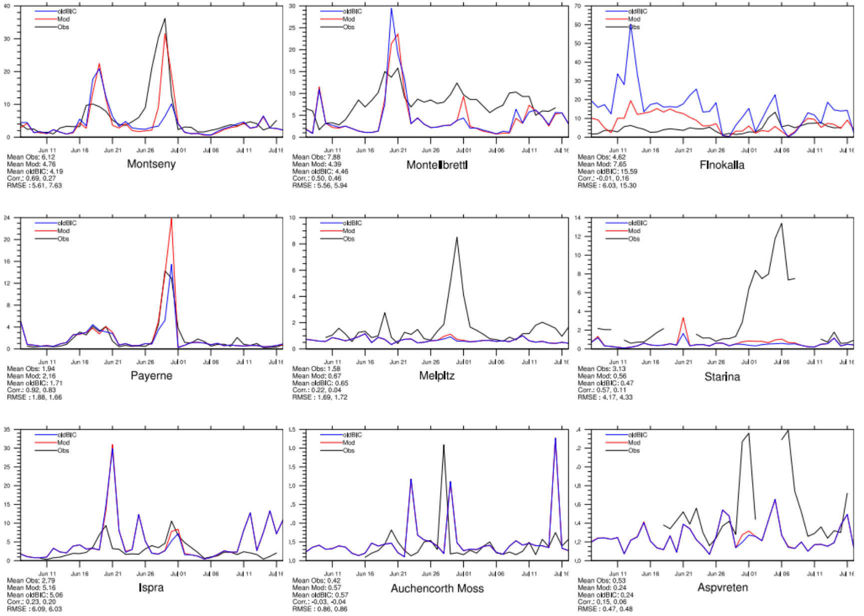
Direct evaluation vs dust conc. from EMEP IMPs in 2012-13

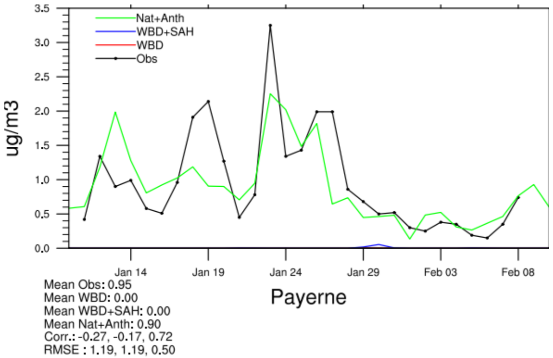


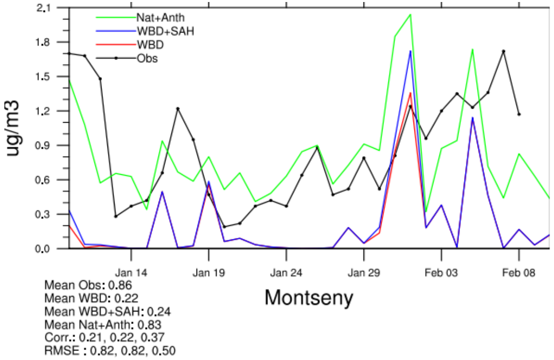
Importance of appropriate boundary conditions for episode reproduction



Role of anthropogenic dust in winter

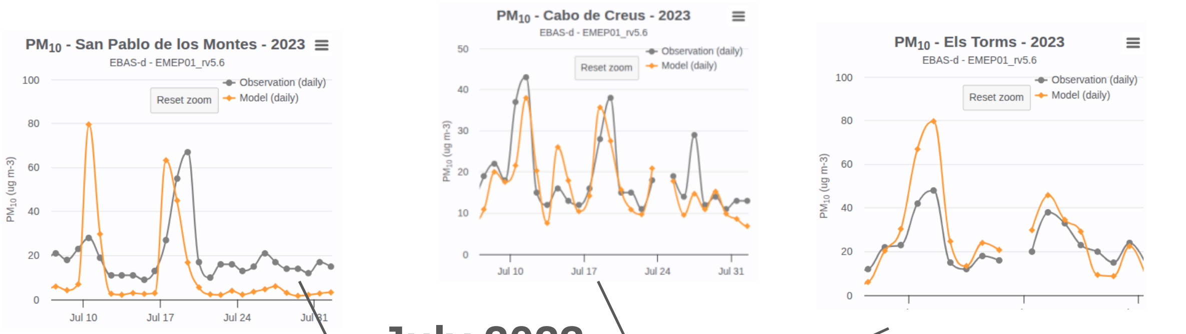


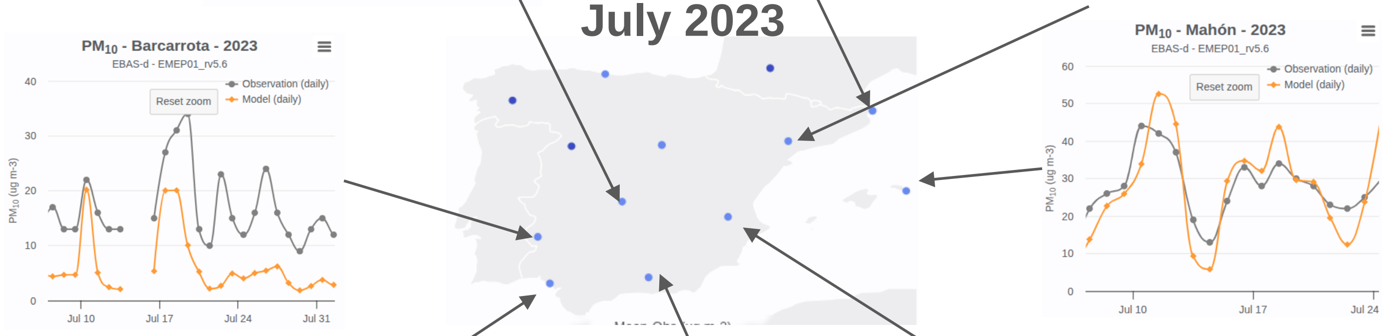


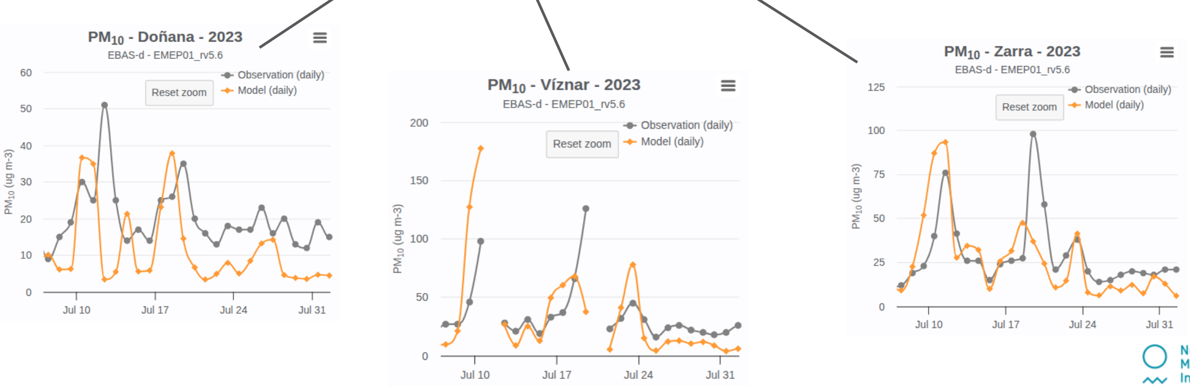


Institute

Evaluation of modelled dust vs proxy observations (1)







Traditional "poor-man's" approach - looking at PM_{10} during (Saharan) dust episodes

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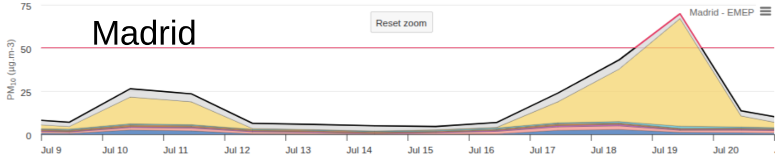
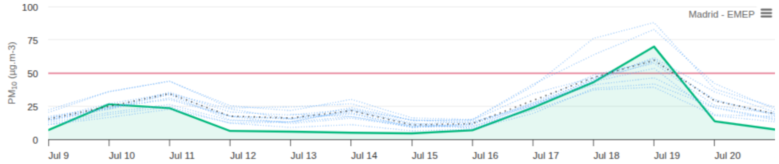
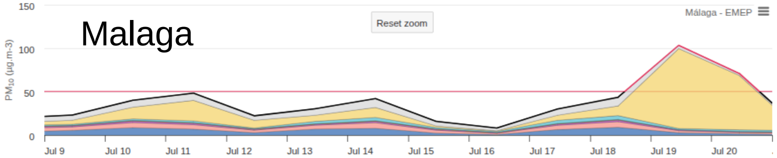
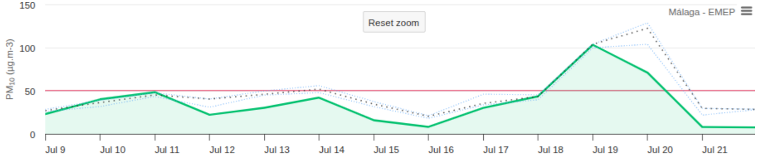
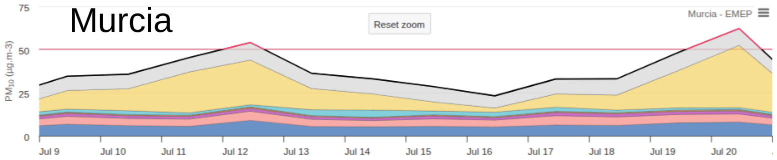
Examples of natural PM episodes forecasts for July 2023

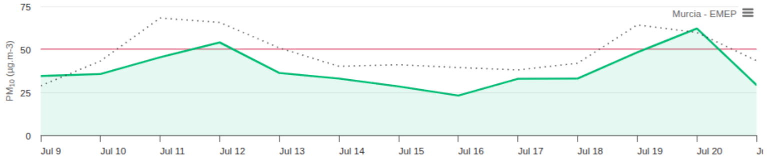








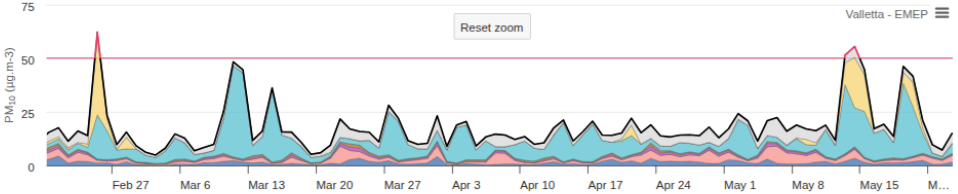


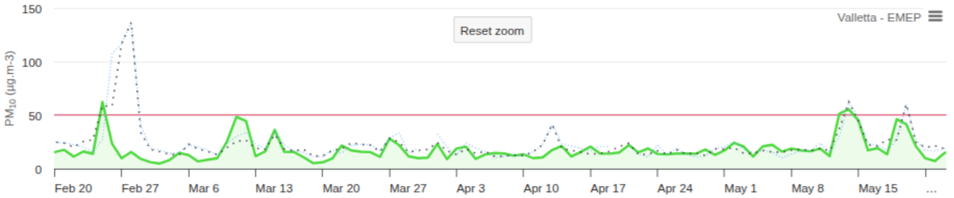


Dust - yellow; sea salt - blue

Comparison with PM10 from EEA AQ sites (urban background)

Valletta, Malta Feb-May 2023





CAMS Policy Support

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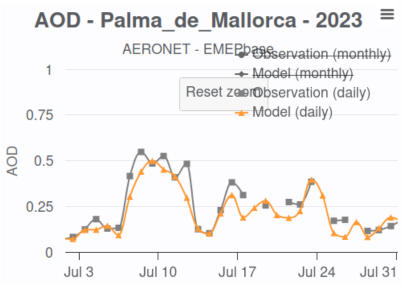
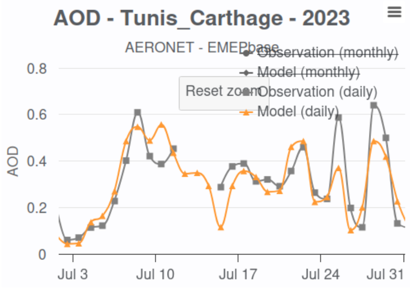
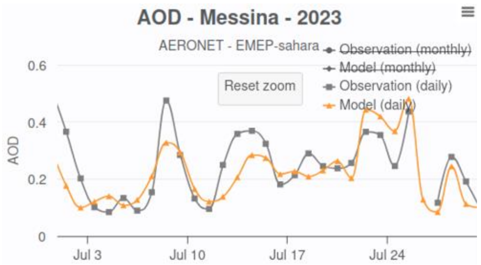
Evaluation of modeled dust vs proxy observations (2) - remote sensing

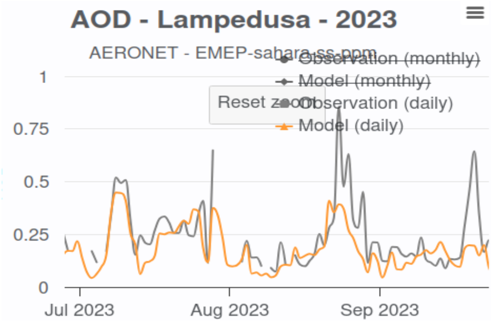
Comparison of modeled AOD against remote sensing observations:
* uncertainties due to description of optical properties (EMEP uses MECs)
* observed AOD includes all aerosols
* in the regions/ during time period when dust is dominant (closer to dust sources, during dust events)

AOD vs AERONET sun-photometers

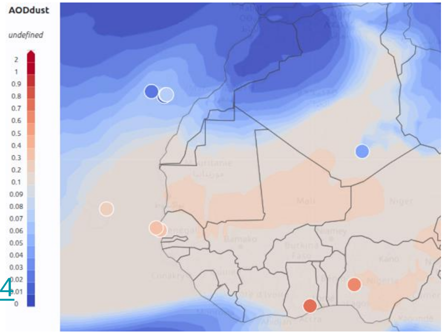




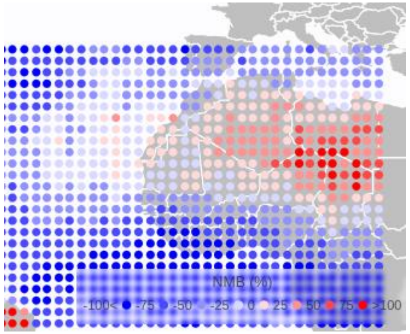




EMEP Dust AOD vs **AERONET coarse mode AOD**



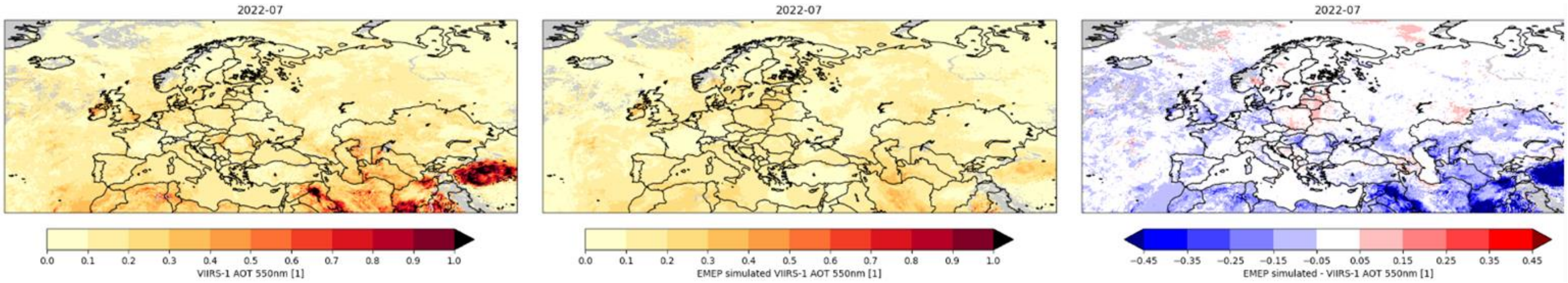
Bias:
EMEP Dust AOD vs **LIVAS Dust AOD** (CALIOP L2 Earlinet)



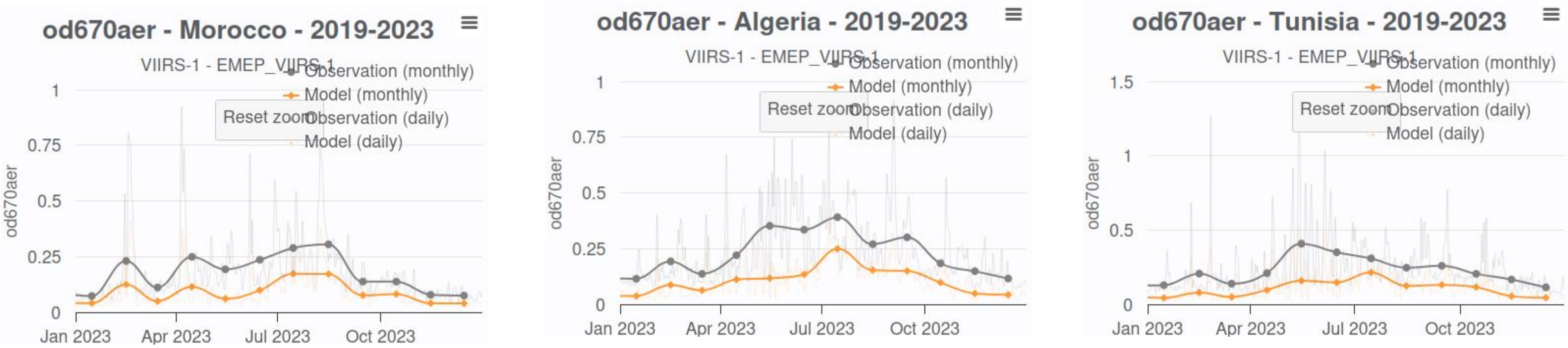
ESA project DOMOS:
https://essd.copernicus.org/articles/17/4351/2025/#section4

EMEP vs VIIRS (NRS SEASAM project)

AOD_550nm for July 2022 (a couple of dust outbreaks):
EMEP underestimate AOD over dust source regions (emission uncertainties, but also coarse size resolution, uncertainties in optical properties etc.)



AOD_670nm in Aeroval: daily timeseries for some source areas



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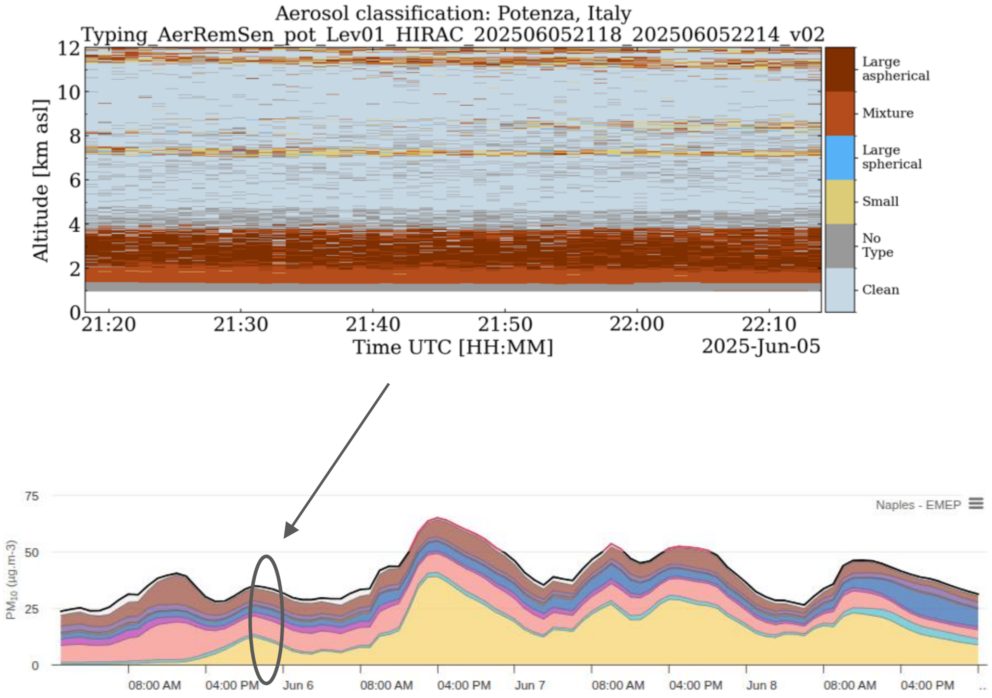
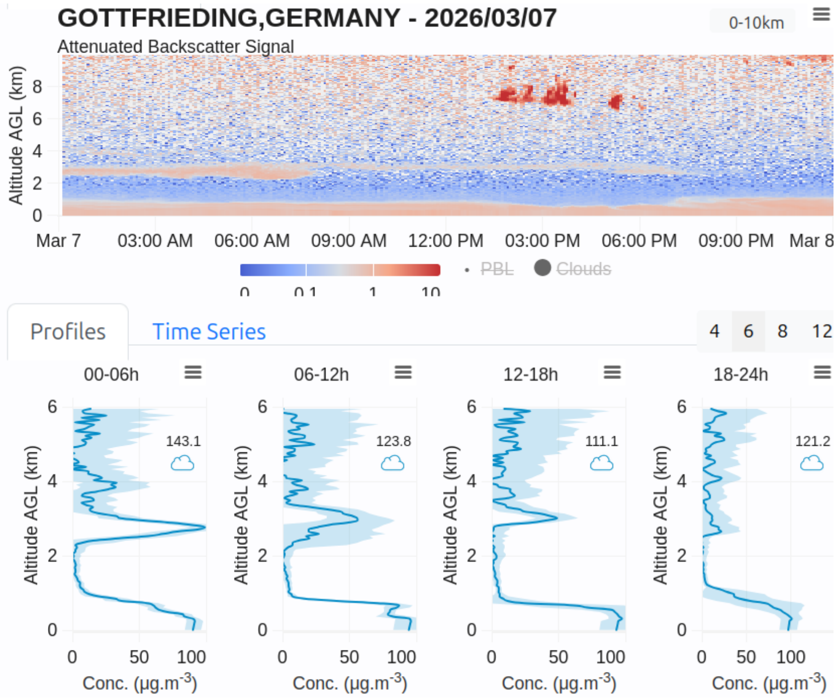
New ‘proxy’ dust observations for model evaluation:

Earlinet aerosol typing



Courtesy of Lucia Mona

Ceilometer profiles



https://vprofiles.met.no/

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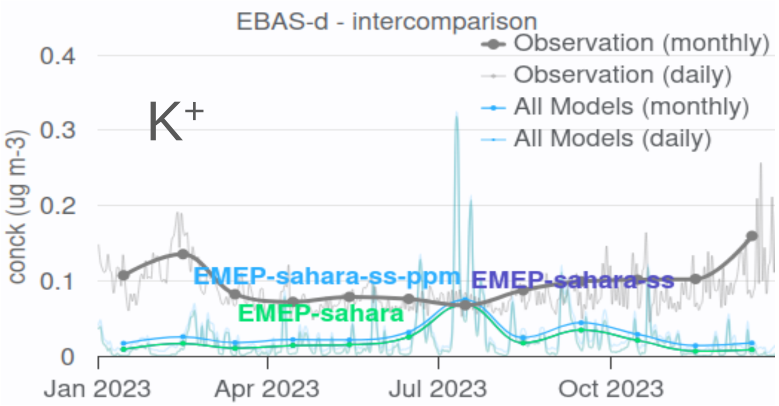
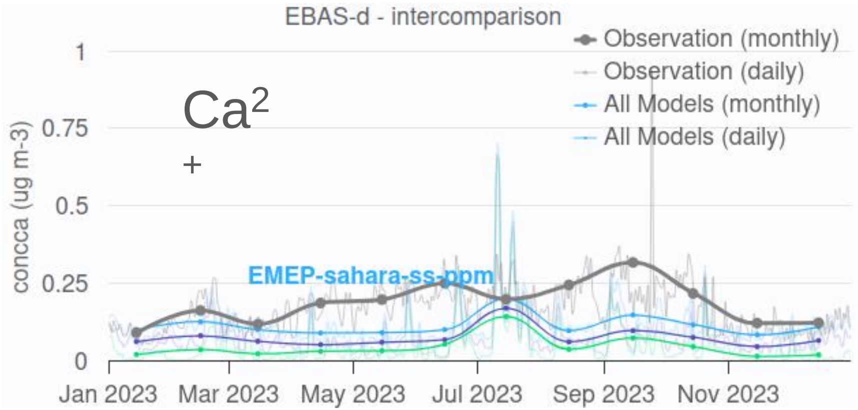
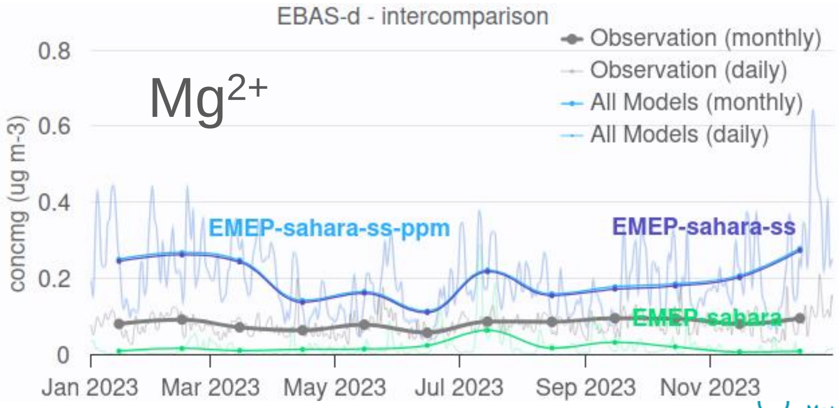
Evaluation of modelled dust vs proxy observations (3) - against EMEP measured base cations: Ca, Mg, K, Na (on-going AeroVal development)

	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Reference
Saharan dust	0.075	0.030	0.035	0.011	Formenti et al., 2008
Sea salt	0.012	0.077		0.31	Average sea water
Anthropogenic dust: fine coarse	0.088 0.046	0.0105 0.0074	0.0191 0.0091	0.0074 0.0113	Van Loon, Tech.Rep MSC-W, 2005







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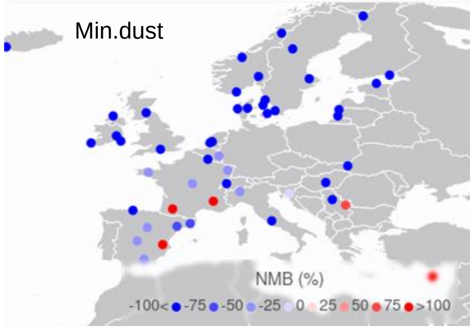
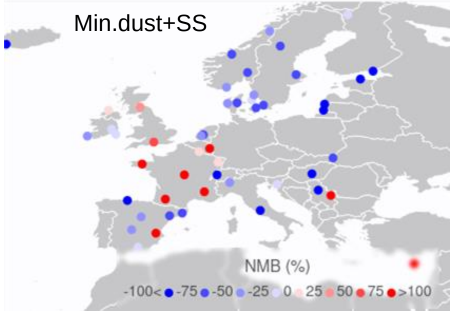
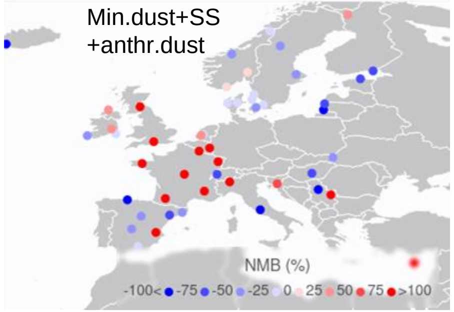
AeroVal prototype for base cations evaluation

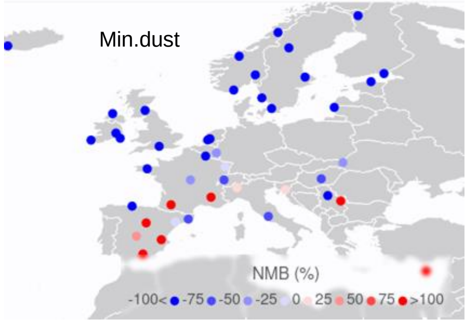
Ca^{2+}

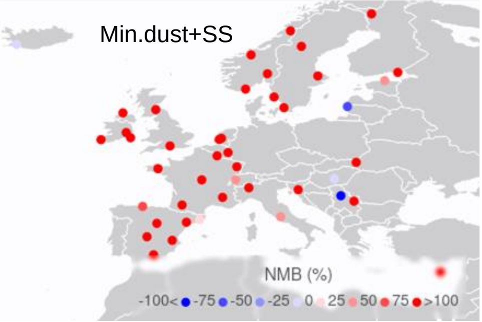




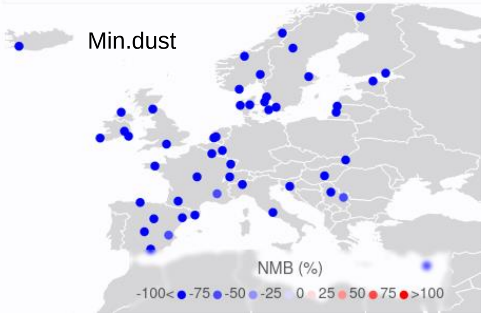


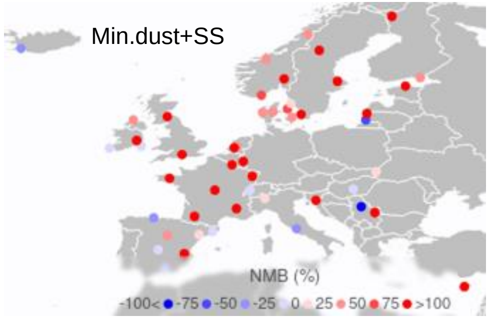
Mg^{2+}





Na^{+}





ALL - 2023

monthly data

		EMEP-sahara-ss-ppm	EMEP-sahara-ss	EMEP-sahara
PM10	EBAS-d	-11.5	-11.5	-11.5
concca	EBAS-d	-41.2	-59.9	-77.2
conck	EBAS-d	-72.2	-79.5	-79.5
concmg	EBAS-d	144.1	138.4	-76.3
concna	EBAS-d	23.7	23	-99.1
AOD	AERONET	-17.2	-17.2	-17.2

NMB (%): 100, 50, 0, -50, -100

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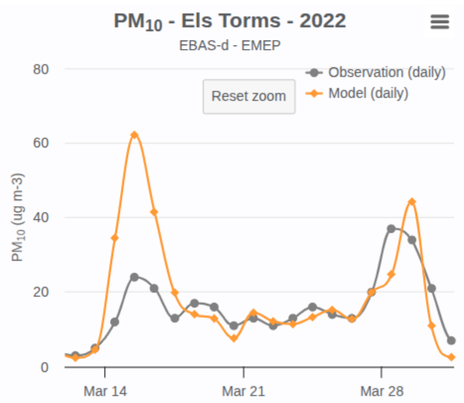
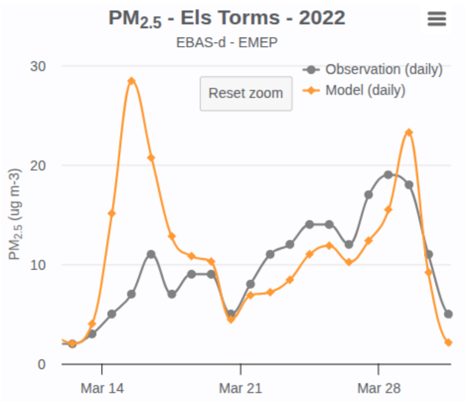
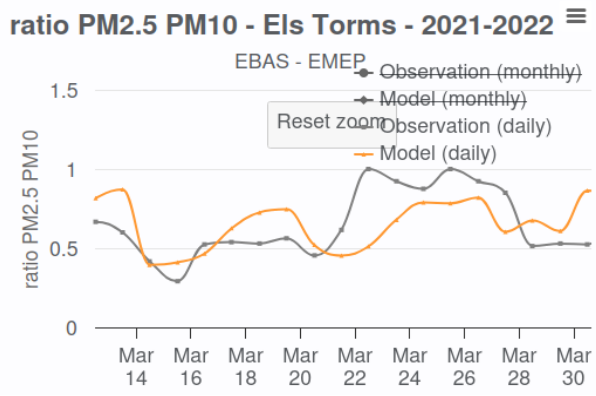
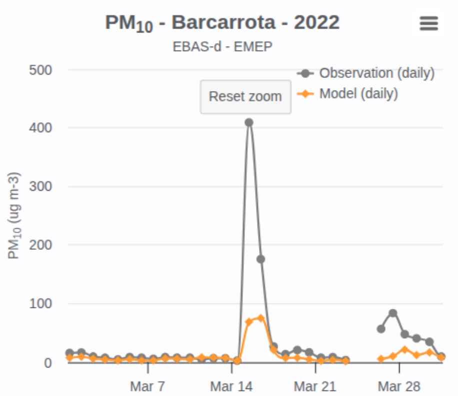
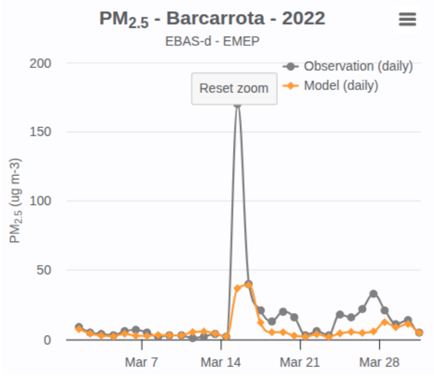
Evaluation PM25/PM10 ratios during dust episodes

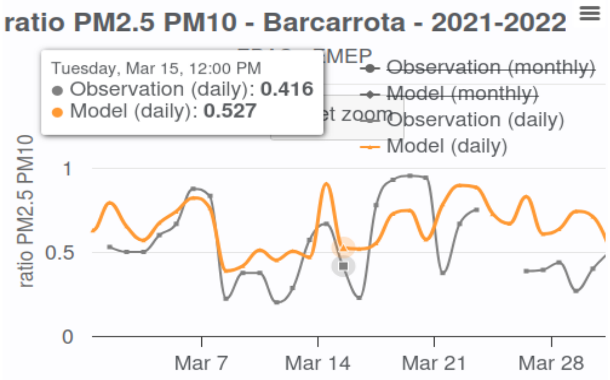




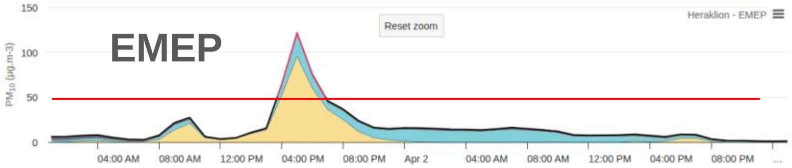


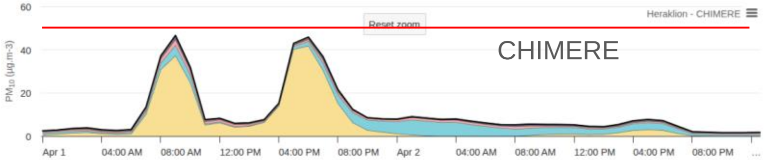


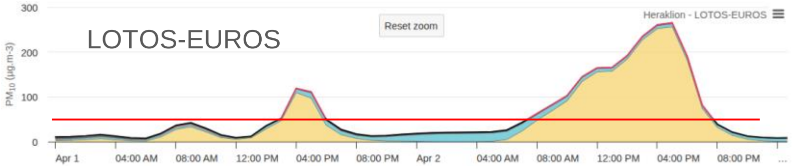


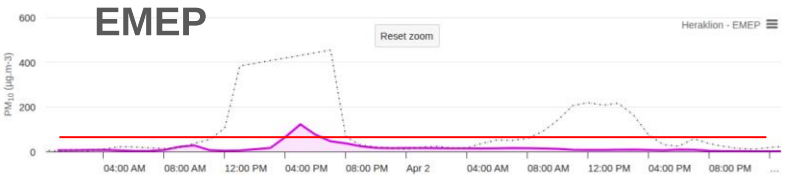


Learning from comparison with other CAMS models









EMEP model

> reproduces most dust events, but happens to miss dust plumes in some cases
> tends to simulate lower dust peaks (but instead do not have extreme overshooting)
> relatively short transport
> relatively less dust at surface, while more aloft

Possible causes for differences in model simulated dust:

- differences in dust generation schemes
- differences in erodible soil maps - dust generation in different areas, the dust plumes can follow different trajectories
- dust size distribution (dry deposition rates)
- dust uplift, transport altitudes

Norwegian Meteorological Institute

$$u_{*,\mathrm{th}} = \frac{u_{*,\mathrm{sm}}}{f_{\mathrm{eff}}} f_w \qquad f_w = \sqrt{\left(1 + 121\,(w - w')^{0.68}\right)}$$

$$f_{\mathrm{eff}} = 1 - \left(\frac{\ln\left(\frac{z_0}{z_{0,\mathrm{s}}}\right)}{\ln\left(0.35\left(\frac{10}{z_{0,\mathrm{s}}}\right)^{0.8}\right)} \right) \qquad w = 0.14\,F_{\mathrm{clay}}^2 + 0.17\,F_{\mathrm{clay}}$$

Z_0 - derived from satellite based scatterometers

+ AOD based model training (SILAM, FMI)

$$\boxed{u_* \geq u_{*,\mathrm{th}}.}$$

$$Q_{\mathrm{s}} = \frac{C\rho_{\mathrm{air}}}{g} u_*^3 \left(1 - \frac{u_{*,\mathrm{th}}}{u_*}\right)\left(1 + \frac{u_{*,\mathrm{th}}}{u_*}\right)^2$$

K - erodibility

*K= 0.08*clay_fr +1.0*(silt1_fr+silt2_fr) +0.12*sand_fr*

$$F = A_{\mathrm{s}} K \alpha\, Q_{\mathrm{s}}$$

$$a = 10^{0.134\,(\%\ \mathrm{clay}) - 6}$$

Sediment supply map (Parajuli&Zender, 2017)

Data based dust scheme - need for observations!

Summary

Modelling of natural dust is associated with significant uncertainties

Status:

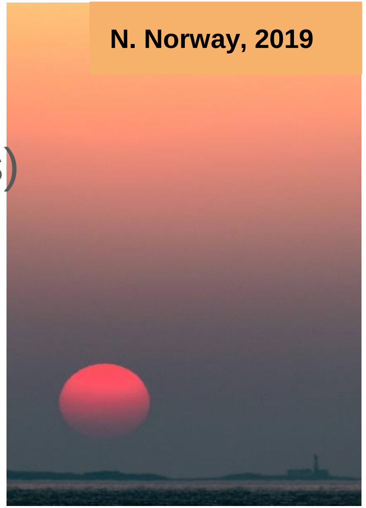
- Model results for dust contribution to PM: annual and events
- Evaluation options
- Identified issues

Challenges for improvements:

- Strong dependence on meteo (wind, precipitation), soil maps/properties - subgrid-level processes
- Uncertain empirical parameters involved in dust parameterization
- Observations to constrain the model (calibration of dust emissions)

Ways forward:

- Data based dust source function
- Using all available observational 'proxy'
- But there is strong need for dust observational data (even campaign measurements help a lot!)



Thank you for your attention