Modeling global aerosols with the SILAM model

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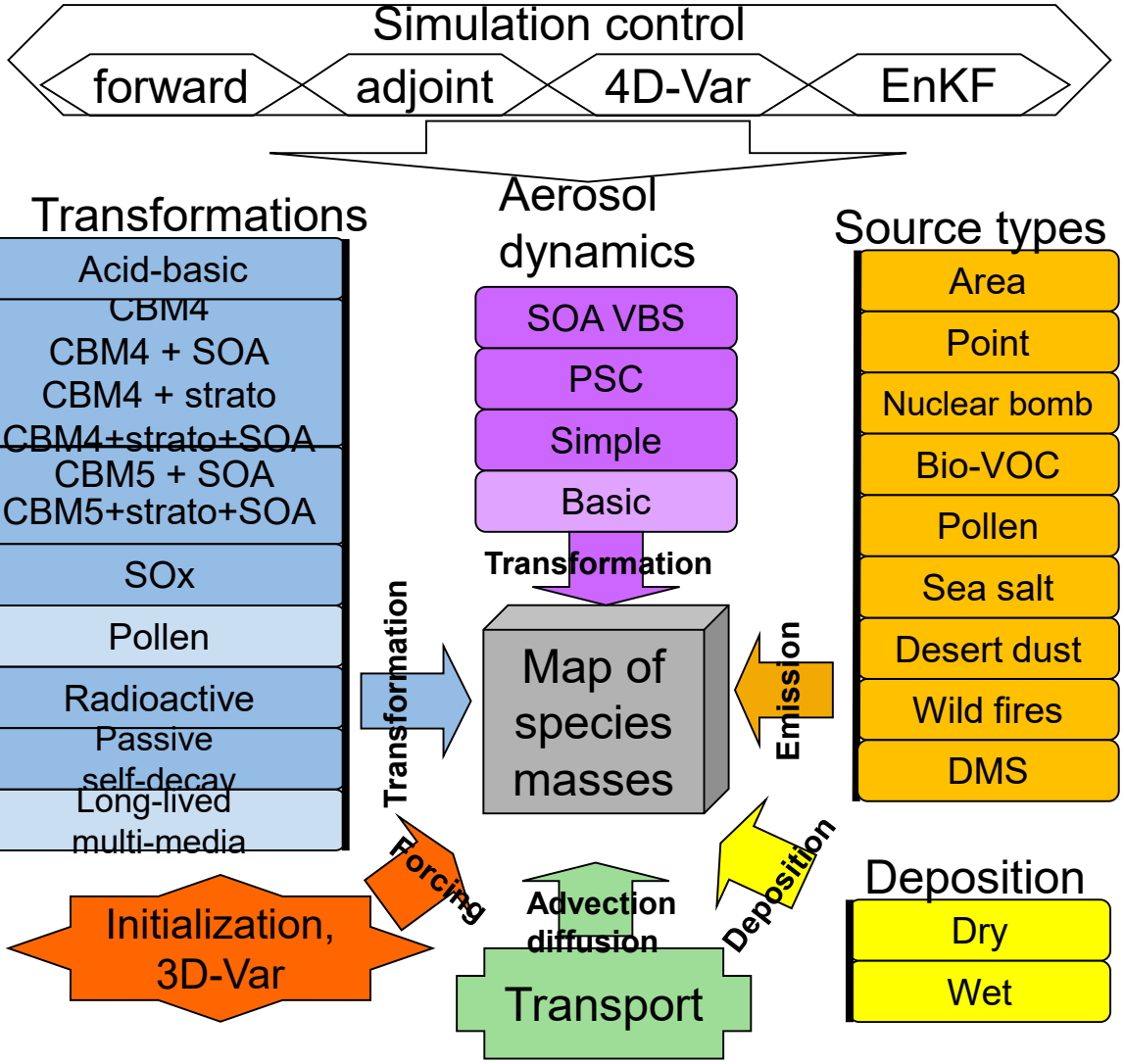
SILAM v.5.8

- Modules
  - 14 chemistry transformation modules
  - 9 source terms,
  - All modern data assimilation techniques: 3D-Var,,4D-Var, EnKF, EnKS
- Domains: from global to beta-meso scale (~1 km resolution)
- Any meteo input that follows WMO standards
- Technically
  - 192 FORTRAN-2005 modules, ~250 classes, OMP+MPI parallel
  - 18 MB of code (~130,000 lines)
  - The largest FMI own model
  - Installed in a dozen of countries for research and operational purposes
  - ~10,000 lines in ~100 environment scripts (Python-Shell)



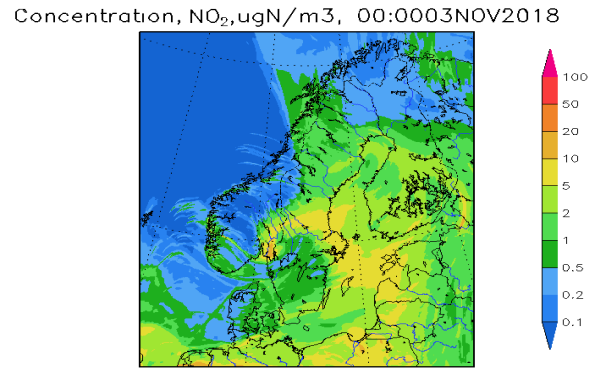
Aerosols in SILAM

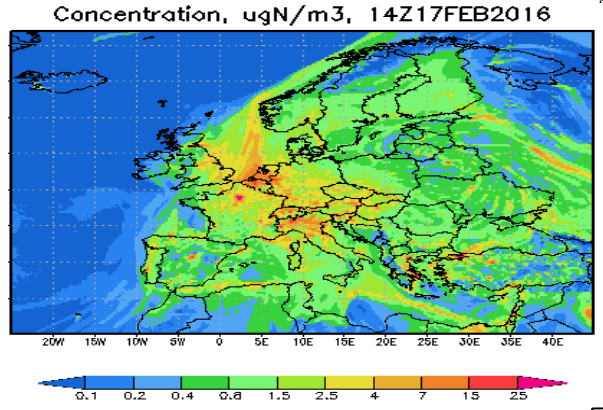
- Primary aerosols
  - Anthropogenic: mineral, EC, OC
  - Biogenic: pollen, fungal spores, aphids (small insects)
  - Sea salt
  - Wind-blown dust
  - Fire-induced EC, OC
  - Toxics: heavy metals, non-volatile persistent organics
- Secondary aerosols
  - sulphates
  - nitrates
  - ammonium (ammonium nitrate)
  - Semi-volatile VOC
  - Toxics: semi-volatile persistent organics
- Representation: sectional, with possibility of sub-sectional size profile
- Volatility scheme: VBS

Rapid evolution

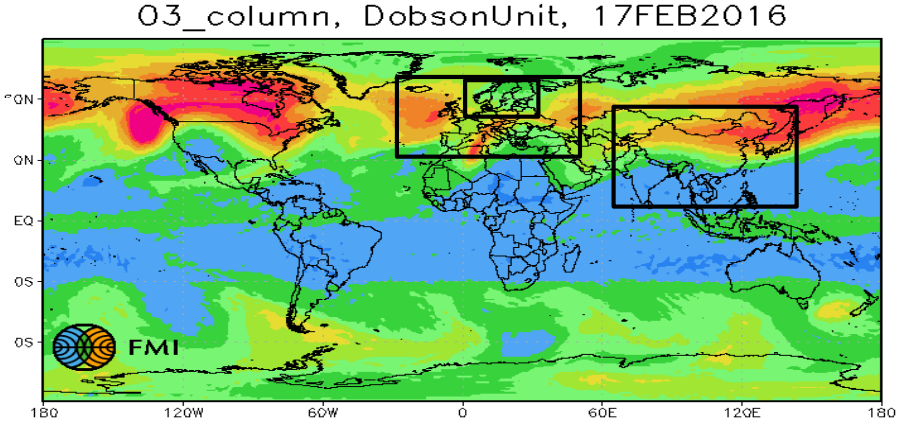
- Since 2018, model updates have been made in several key areas:
  - wet deposition
  - dust emission
  - fire emission
  - anthropogenic emissions
  - CB4 to CB5 chemistry
- Most of these updates were not present at the time of the ICAP multi-model evaluation paper

Operational AC/AQ-modelling



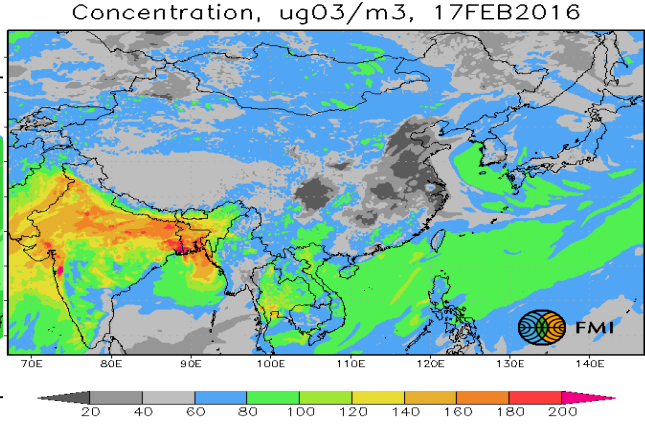


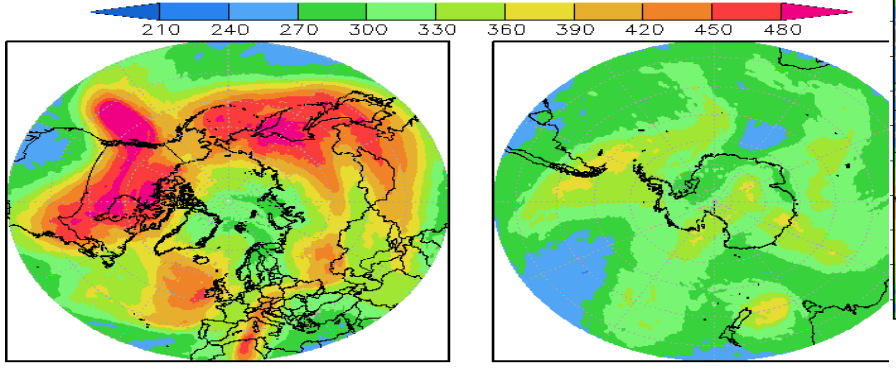
Global: 20km, SILAM v.5.8
troposphere+ stratosphere



Forecast horizon:
5 days glob,
4 days Europe/Asia
2 days Northern Europe
Resolution: 1 hr
http://silam.fmi.fi

Asia: 14km,
troposphere
SILAM v.5.5

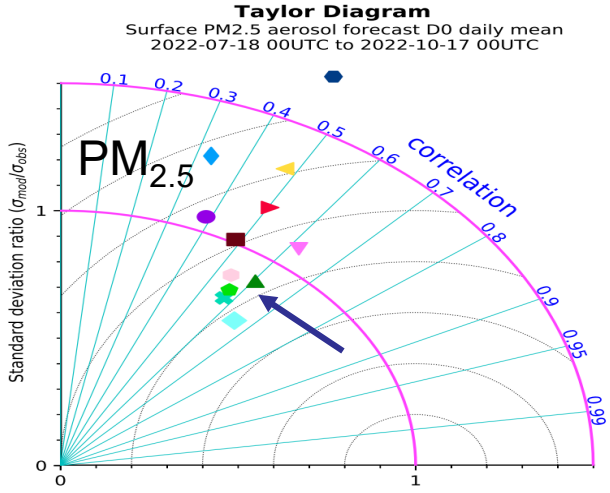


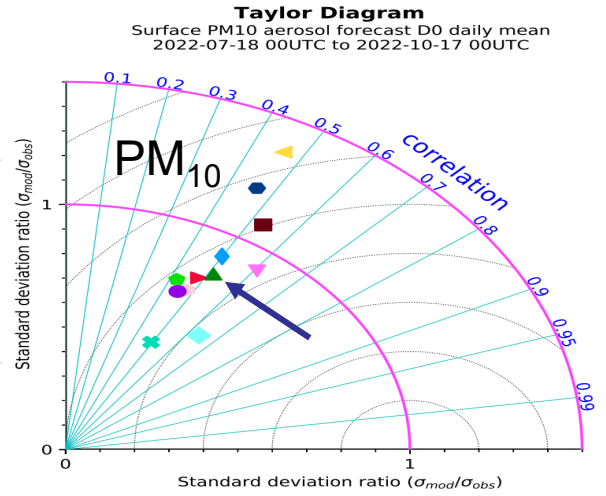


Northern Europe:
2.5km, troposphere

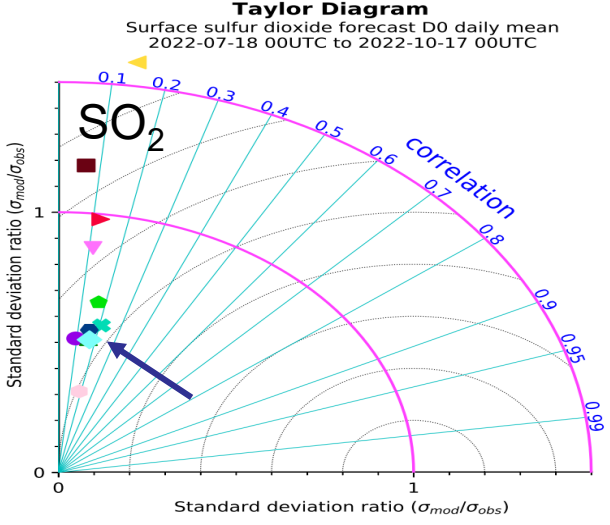
Europe: SILAM v.5.8
10km, troposphere
boundaries: C-IFS
hindcast: 3D-Var

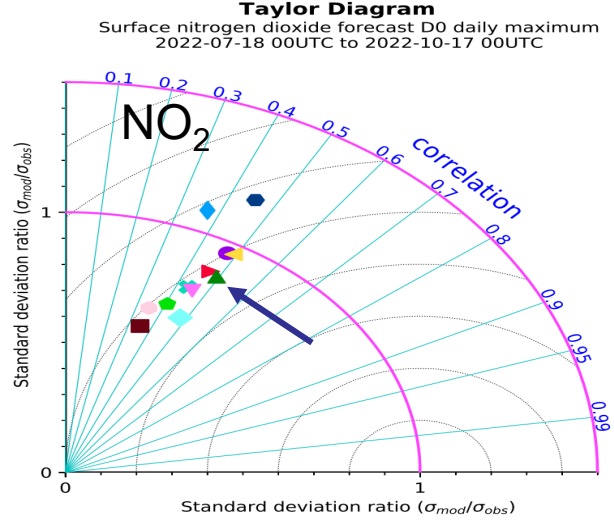
SILAM v.5.7 in Europe

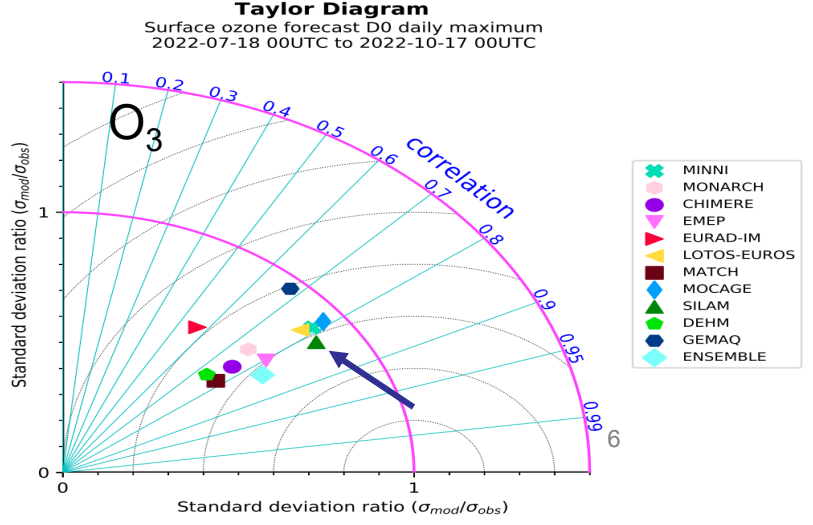




CAMS2_40 evaluation mean
July-October 2022

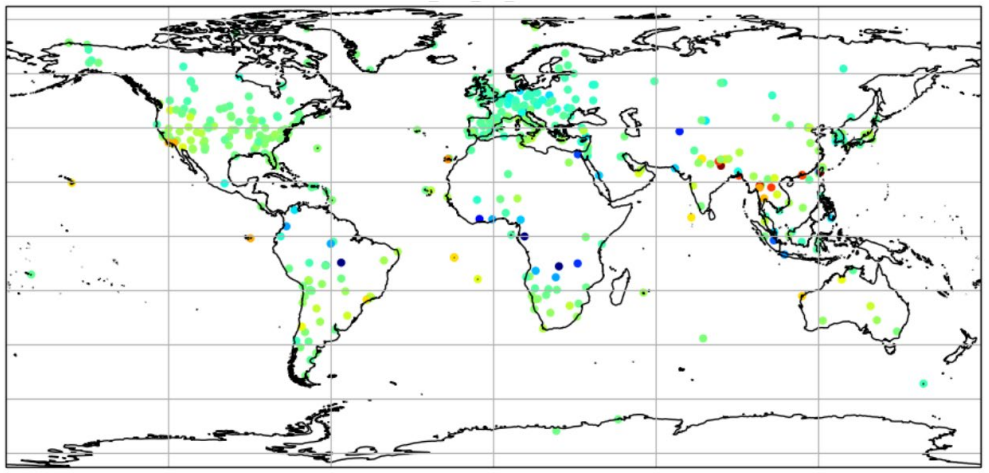


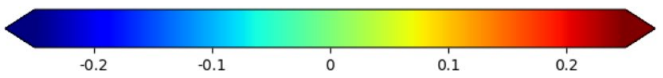




Evaluation against AERONET

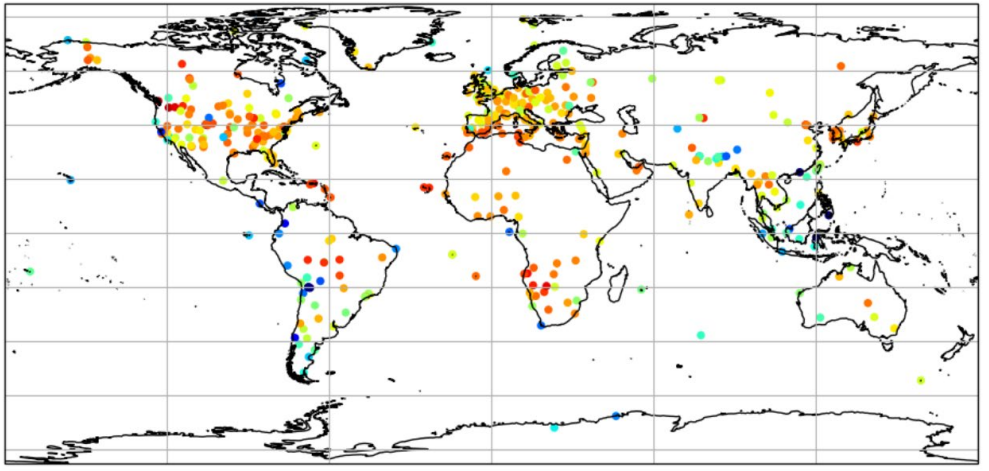
Bias





Model avg 0.157 median 0.108
Obs. avg 0.163 median 0.122

Correlation



Average: 0.64
Median: 0.69
Full: 0.75

Wet deposition development

- Still very much work in-progress
- Due to space limitations, we construct the vertical scavenging profile from the 3D cloud water of the IFS model
- A saturation threshold for the formation of rain
- A maximum scavenging rate based on either the convective available potential energy (CAPE) or the horizontal wind

Fire and sea salt emission

- New emission factors for MODIS FRP
- New diurnal cycles
- Emissions based on VIIRS in development
- Sea salt emission unchanged, but needs improvement: Sovieva, S., AMT, in press

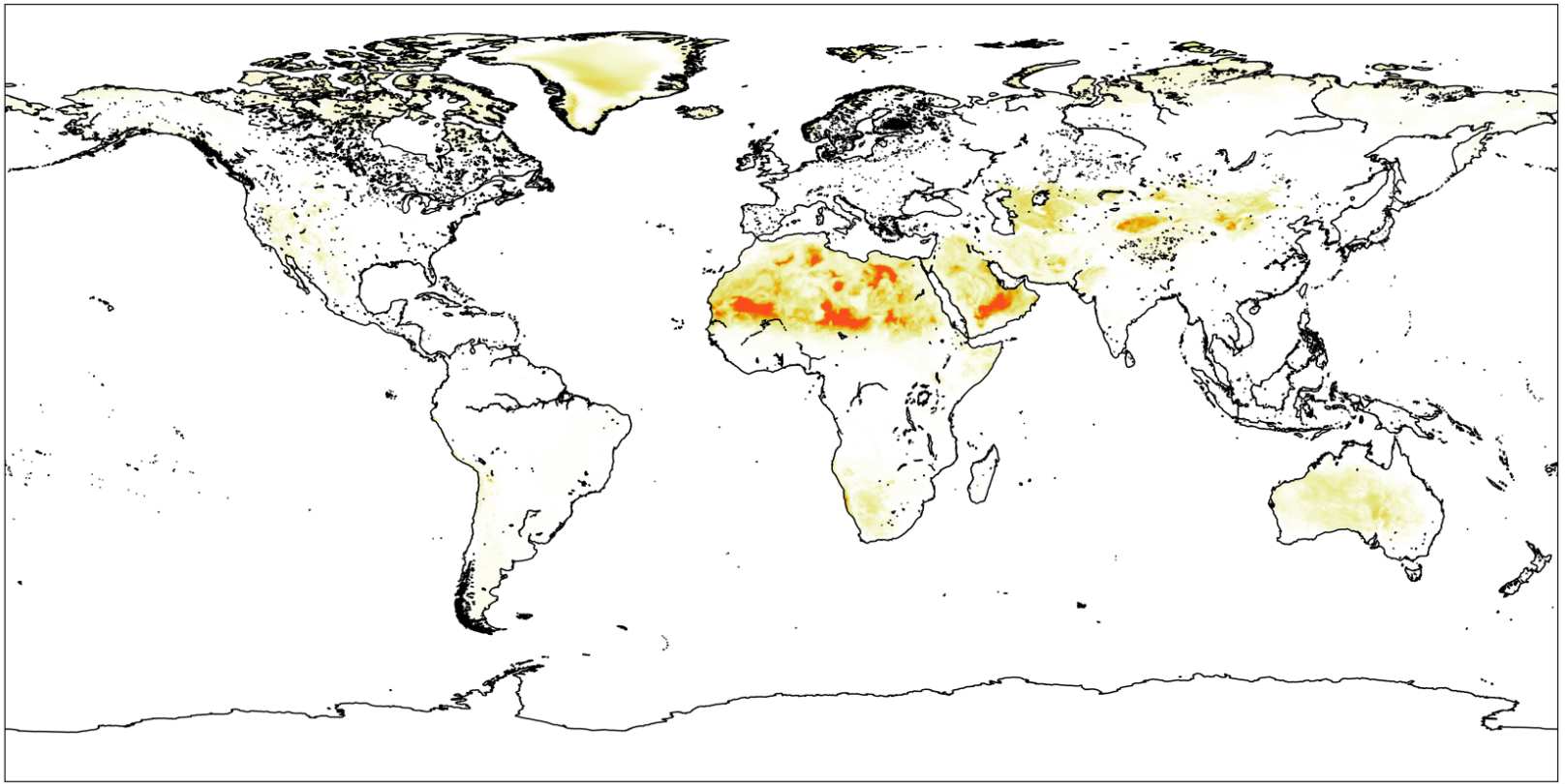
Dust emission model development

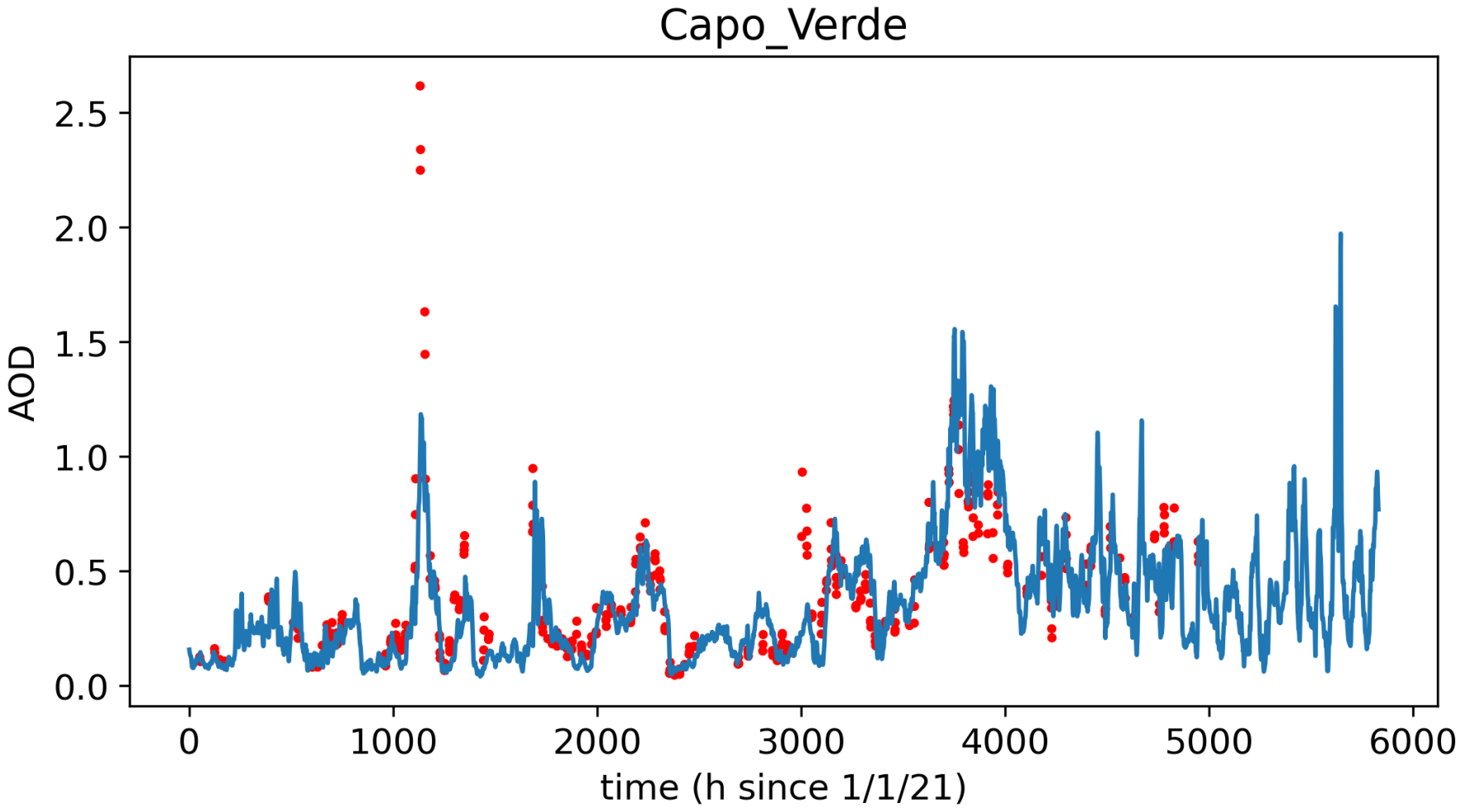
- Previously, our dust emission was based on the friction velocity, calculated from the 10 m wind, as well as many of the bells and whistles that have been published about dust emission
- It did not work for us
- Issues:
  - Strongly nonlinear model applied to model cells of 0.2 deg x 0.2 deg size or larger
  - Scaling of the emission with model resolution
  - Intra-cell correlation of key model parameters: soil type, soil moisture, leaf area index, surface roughness
  - Not accurate description of the impact of the clay content of the soil (crust formation and binding of soil moisture)
  - Inaccurate maps of the key parameters

Dust emission, continued

- Principle: instead of adding even more detail into an already complicated model, start with a really simple effective model
- constant emission map × $(v_{10m} - v_{min})^3$ × soil moisture limiter × snow depth limiter × leaf area index limiter
- v_{min} = 5 m/s
- Constant emission map: surface roughness from wind scatterometer data raised to a negative power

Surface roughness from the ERS wind scatterometer




Capo_Verde
AOD
2.5
2.0
1.5
1.0
0.5
0.0
0
1000
2000
3000
4000
5000
6000
time (h since 1/1/21)

Conclusions and future development

- Our aerosol forecast is strongly impacted by intracell processes that are difficult to model in a physically rigorous way
- No data assimilation: no help from satellites, but there are also significant benefits
- Development is needed in several areas:
  - Sea salt emission / transport
  - Fire emissions in the tropics
  - Data assimilation of emission sources