Aerosol plans at CHMI

Ján Mašek and Ana Šljivić,

with many thanks to colleagues contributing to successful CAR developments!

Introduction

- Developments within CAR (Cloud-Aerosol-Radiation interactions) project reached mature state for radiation part using ACRANEB2 scheme.
- It is time to benefit from them, replacing old Tegen et al. (1997) aerosol climatology by a new CAMS (Copernicus Atmosphere Monitoring Service) aerosols.
- New possibilities offer the use of CAMS:
  - 2D or 3D aerosol climatology;
  - near real time (n.r.t.) aerosols.
- CAR outcomes include not only the development branch above cy46t1_bf.07, but also the tools and procedures for handling CAMS aerosols.
- At CHMI we are going to use CAMS aerosols in both ALARO NWP & ALARO-Climate versions.

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Tegen and CAMS aerosol types

Aerosol type			Default height scale [km]	
Tegen	CAMS		Tegen	CAMS
1 land	ammonium sulfate	SU (sulfate)	1	4
	hydrophilic organic matter	OM1		2
	hydrophobic organic matter	OM2		2
2 sea	sea salt, 3 size bins	SS1, SS2, SS3	1	1
3 desert	desert dust, 3 size bins	DD1, DD2, DD3	3	3
4 soot (urban)	hydrophilic black carbon	BC1	1	1
	hydrophobic black carbon	BC2		1
—	fine mode nitrate	NI1	—	3D n.r.t. only
—	coarse mode nitrate	NI2	—	3D n.r.t. only
—	fine mode ammonium sulfate	AM (ammonium)	—	3D n.r.t. only
5 sulfate	(stratospheric volcanic ashes)	optical properties of OM2	N/A	N/A
6 volcanic	(stratospheric volcanic sulfates)	optical properties of SU	N/A	N/A

Commonly used short names “sulfate”, “volcanic” and “ammonium” are ambiguous!

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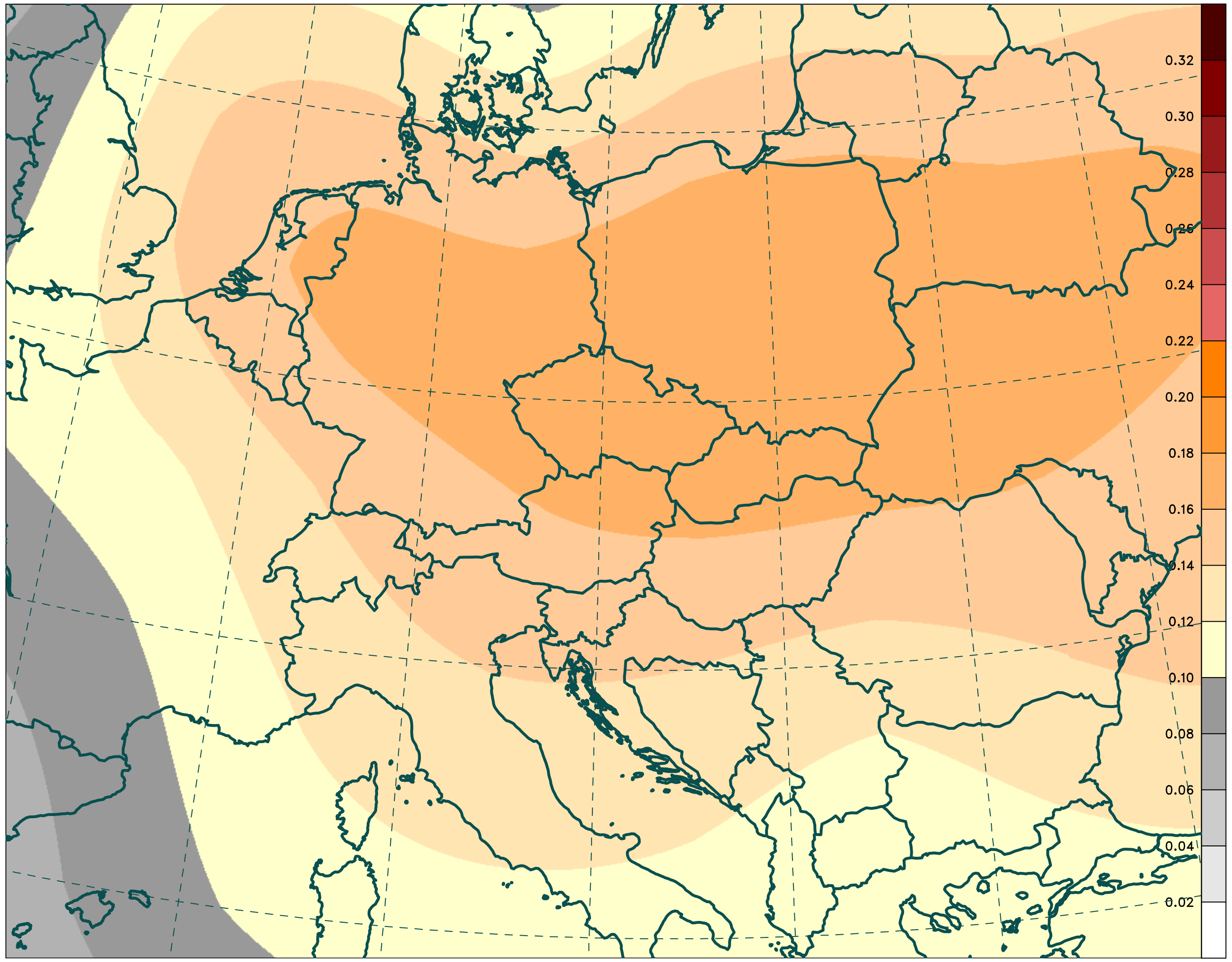
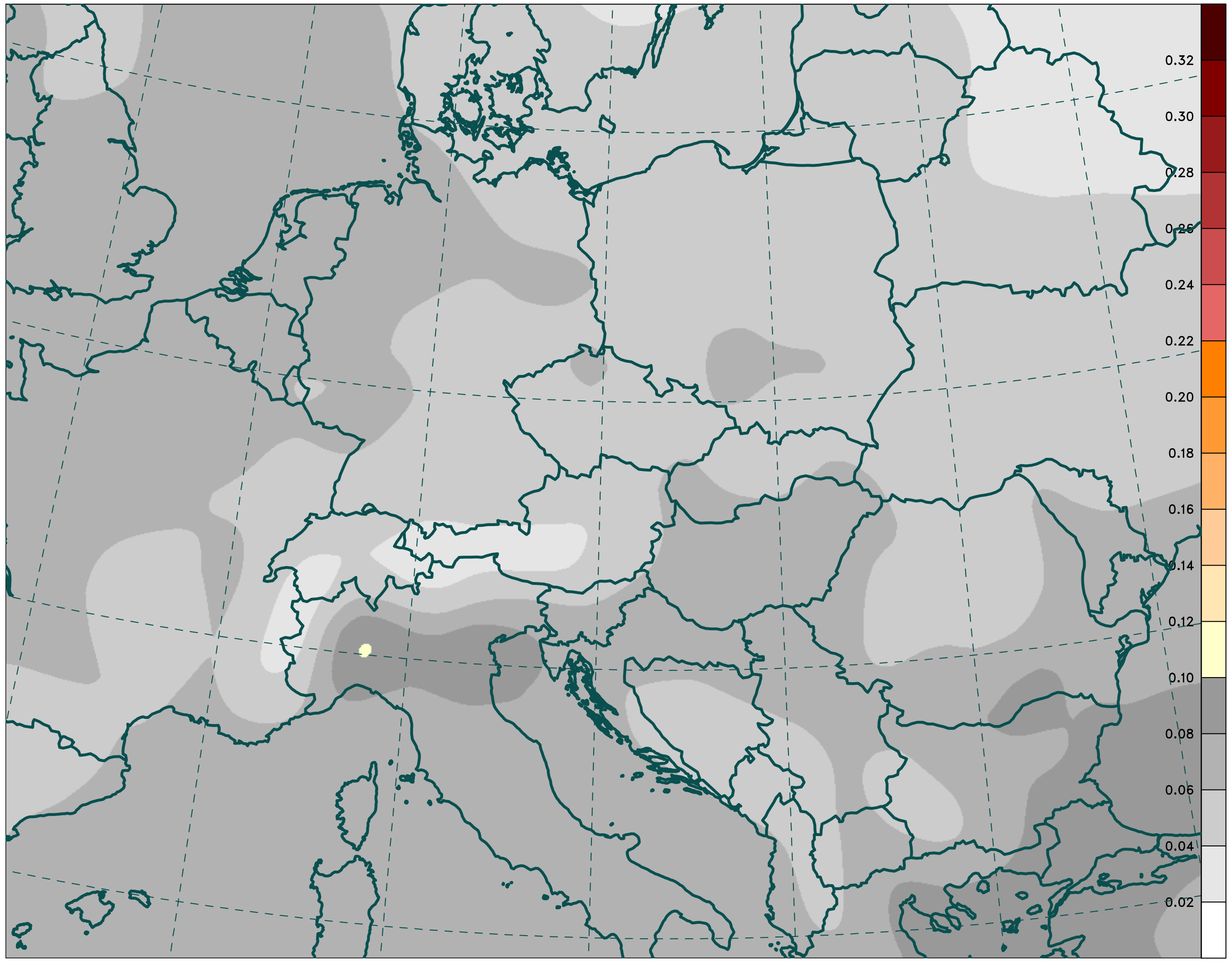
Tegen versus CAMS climatology: January

Tegen ($5^\circ \times 4^\circ$)



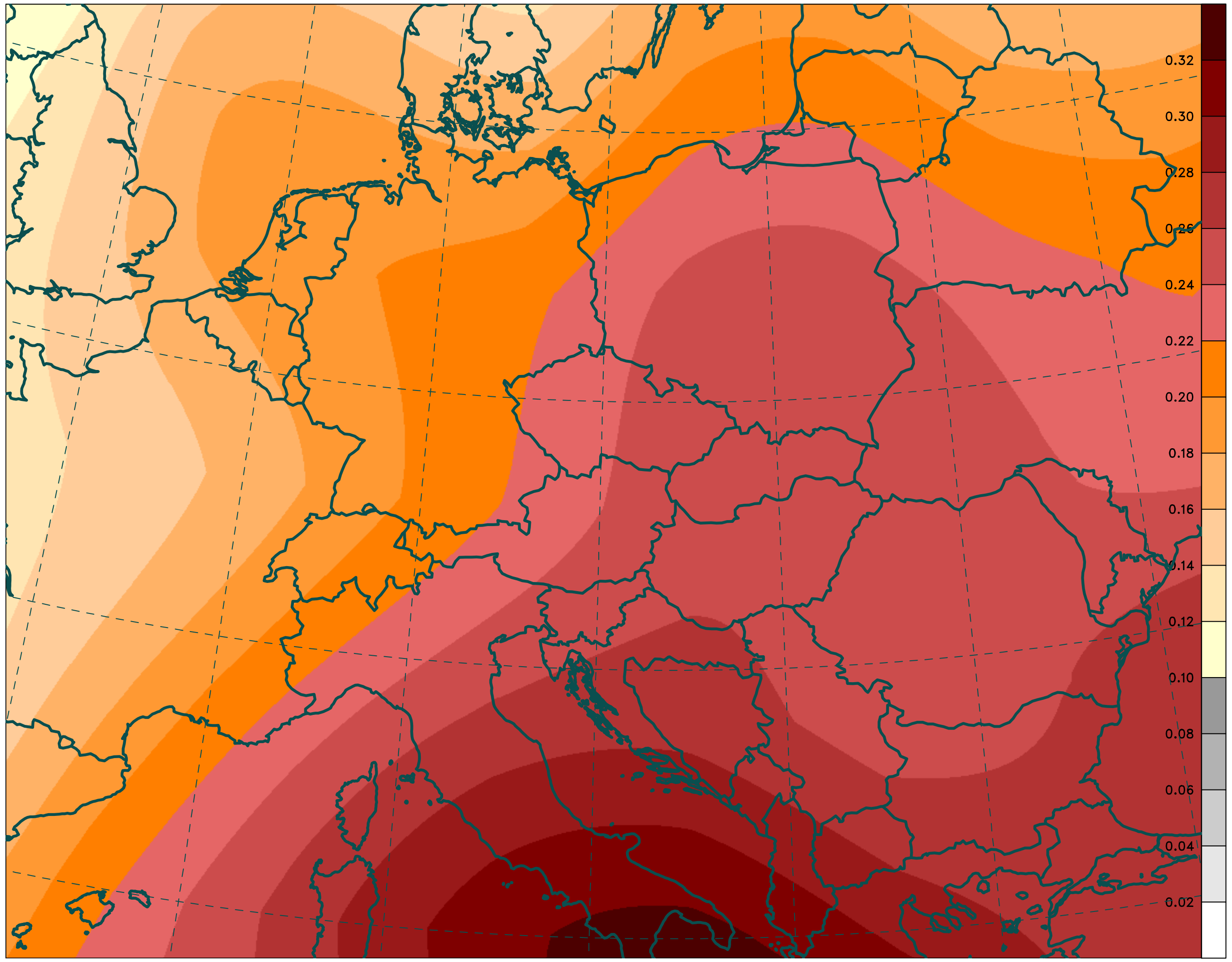
CAMS ($0.75^\circ \times 0.75^\circ$), RH = 65%



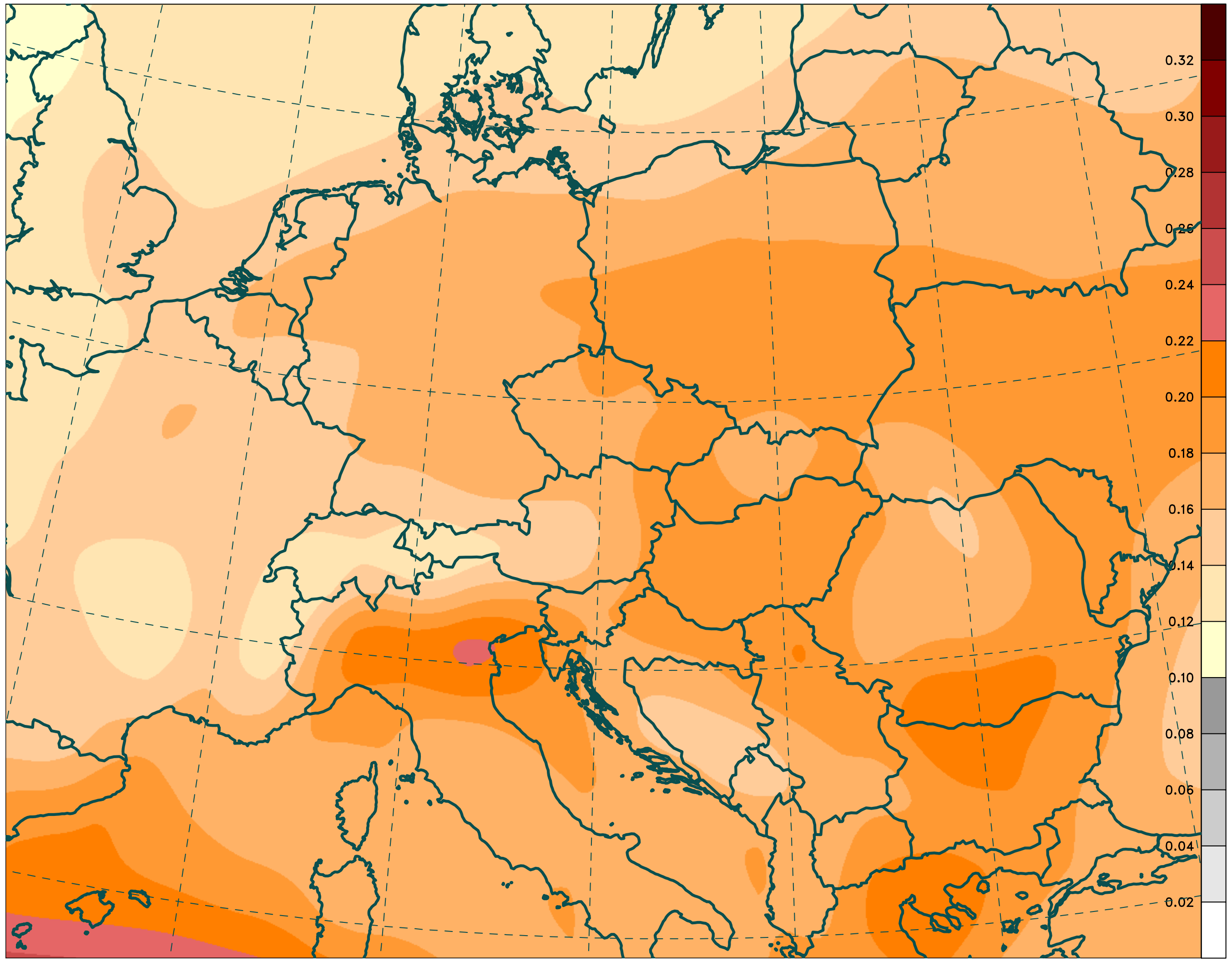
Total AOD at 550 nm; mixture of all tropospheric aerosols. Gray to color transition at AOD = 0.1.

Tegen versus CAMS climatology: July

Tegen (5° × 4°)



CAMS (0.75° × 0.75°), RH = 65%



Total AOD at 550 nm; mixture of all tropospheric aerosols. Gray to color transition at AOD = 0.1.

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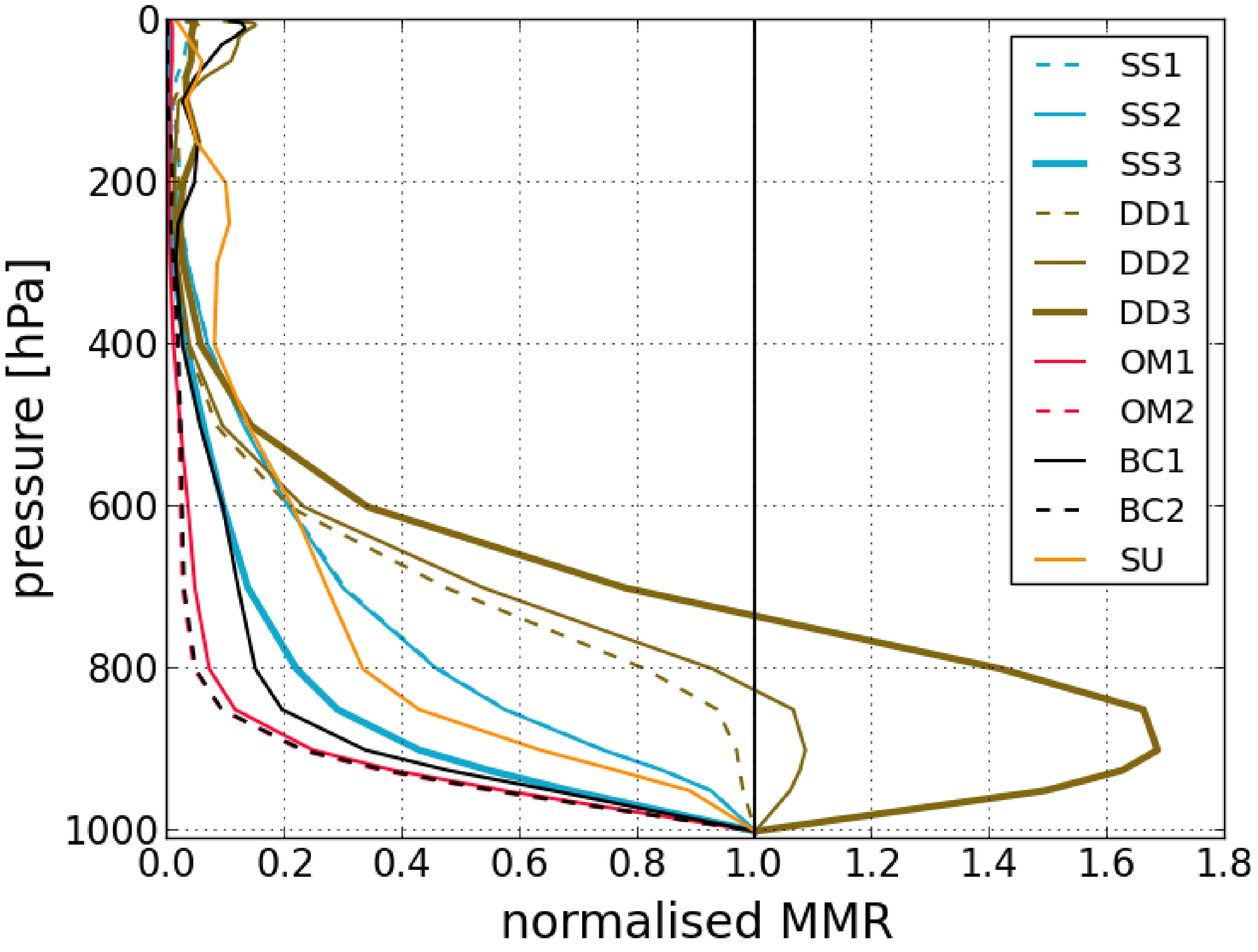
Vertical distribution of CAMS troposheric aerosols

averaged profiles (Europe, 2003–2022)



idealized profile for 2D $\to$ 3D conversion

$$r_{\mathrm{aer}}(z) = C \times \left(\frac{z}{H_{\mathrm{aer}}}\right)^{\beta-1} \exp\left(-\frac{z}{H_{\mathrm{aer}}}\right)$$

r_{aer} – aerosol mass mixing ratio

z – height, H_{aer} – aerosol height scale

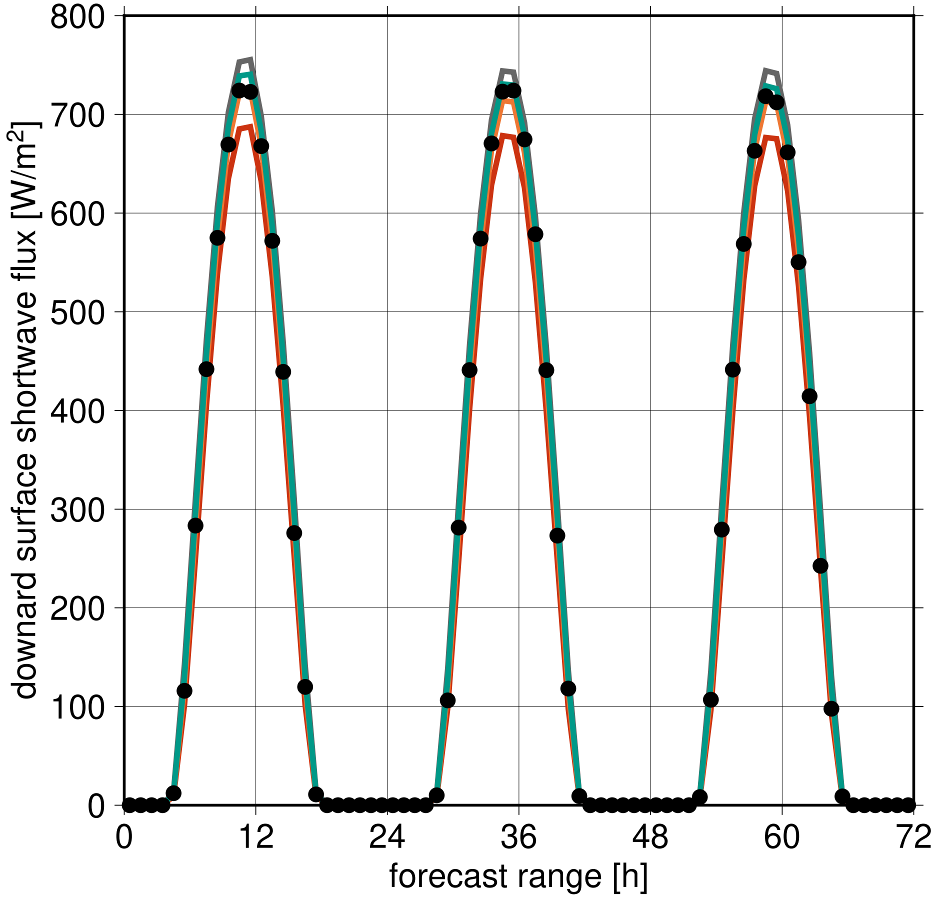
C – calibration constant

β – exponent of gamma distribution:

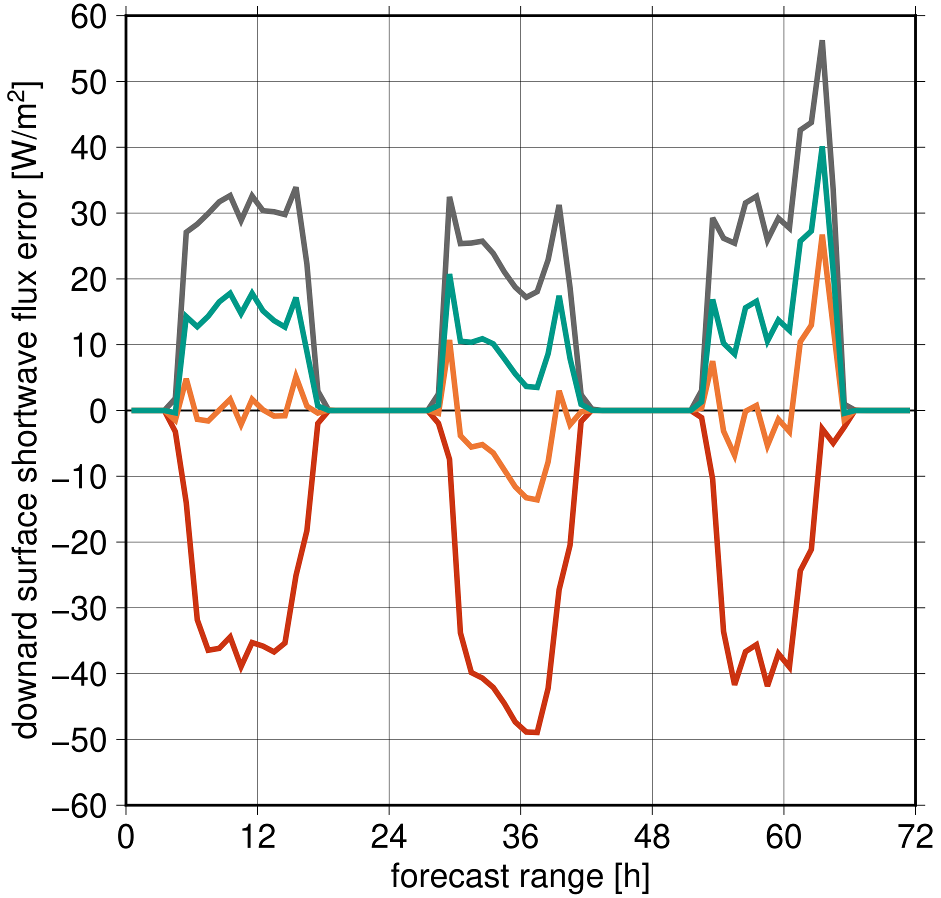
- default value $\beta = 1$ gives back exponential distribution in z alias power distribution in pressure
- $\beta = 1.3$ can be used for DD2, DD3

Aerosol impact on global radiation in clearsky case (7–9 September 2023)

global radiation, Prague



error of global radiation, Prague



background AOD:

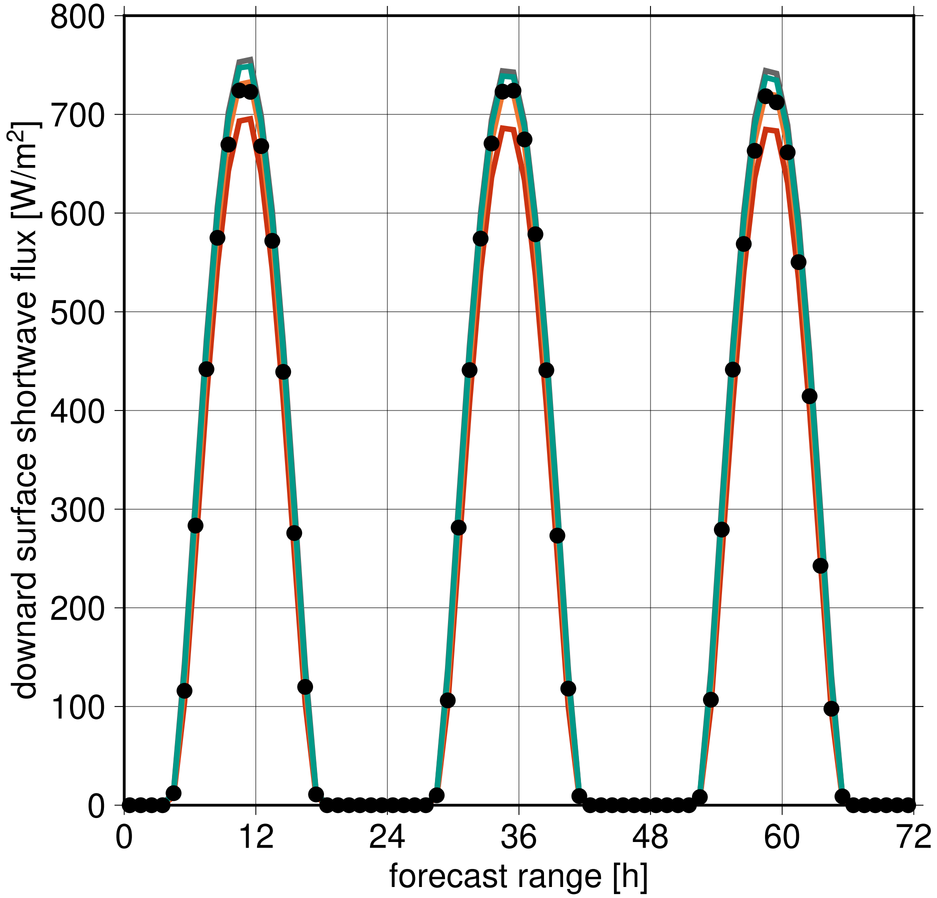
TRBKG = 0.030
STBKG = 0.045
volcanic ashes = 0.007
(hardcoded)

0.082

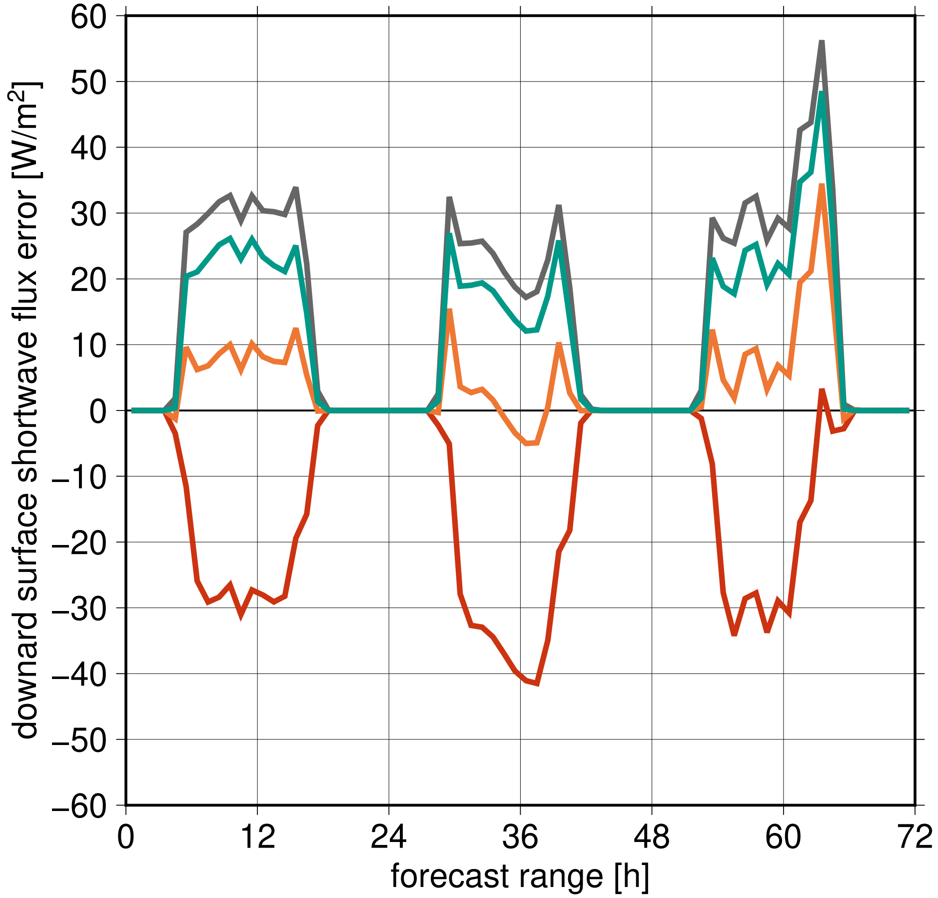
- no aerosols
- Tegen climatological aerosols
- CAMS 2D climatological aerosols
- CAMS 3D near real time aerosols

Aerosol impact on global radiation in clearsky case (7–9 September 2023)

global radiation, Prague



error of global radiation, Prague



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(hardcoded)

0.000

no aerosols

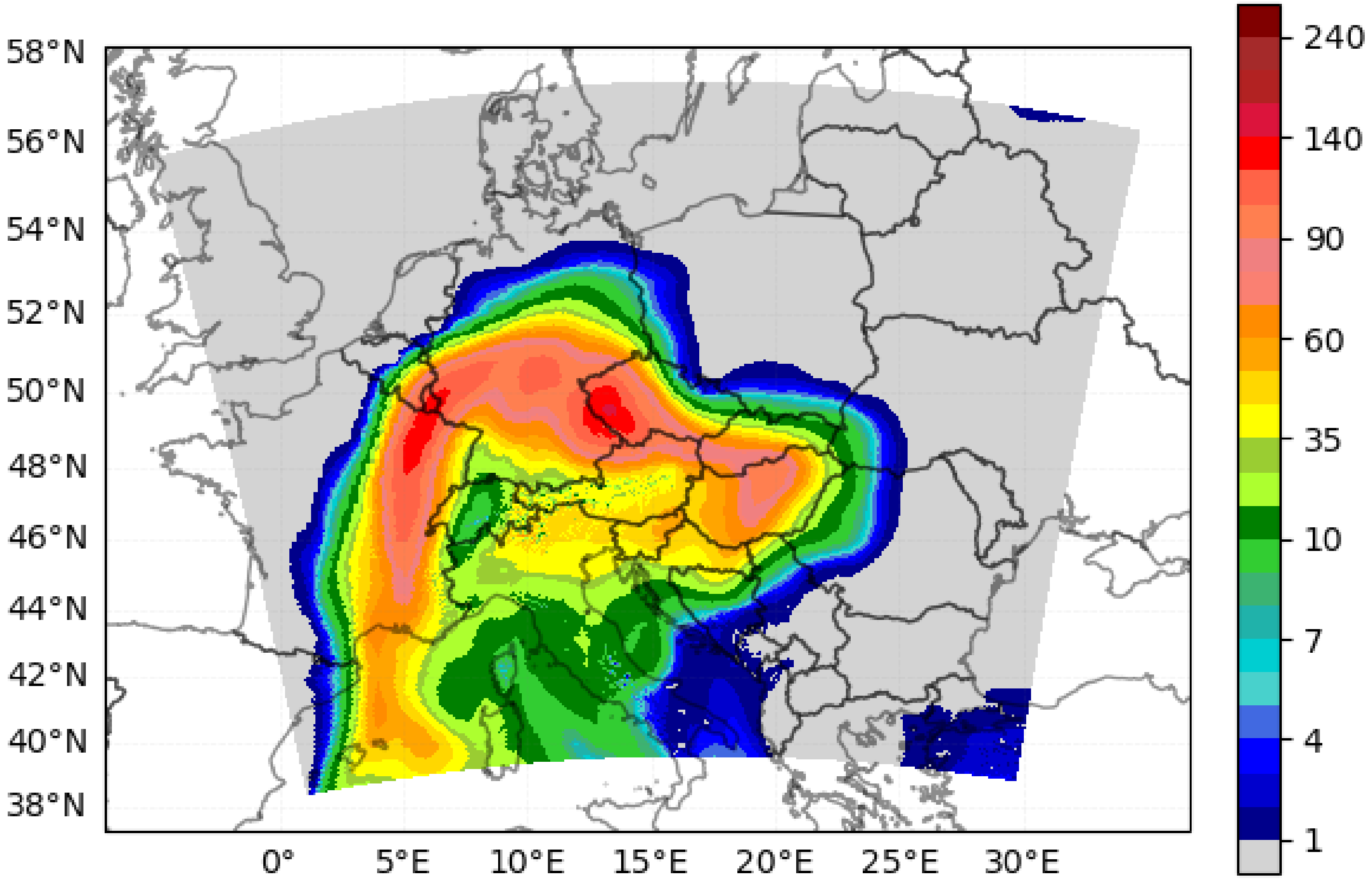
Tegen climatological aerosols

CAMS 2D climatological aerosols

CAMS 3D near real time aerosols

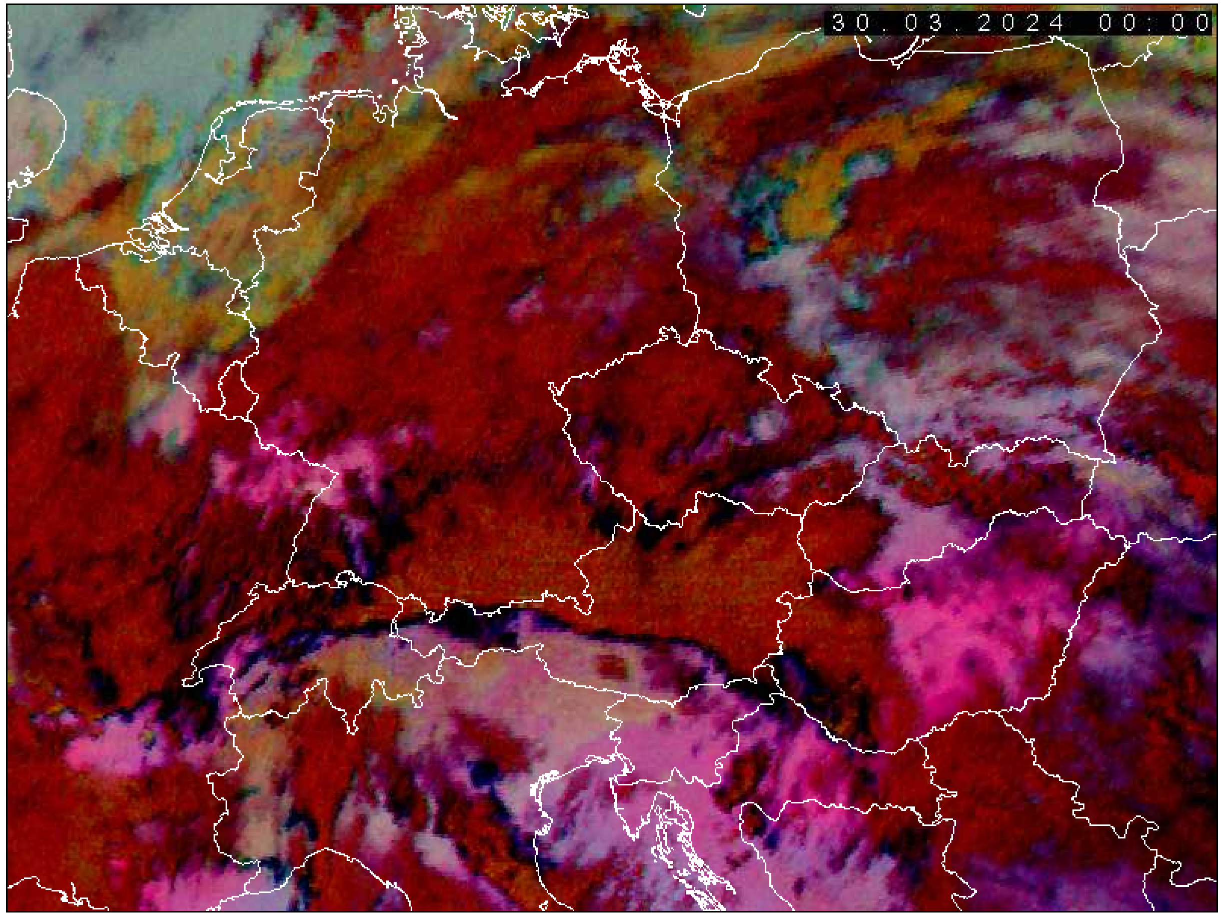
Intrusion of Saharan dust (30 March 2024, 00 UTC)

vertically integrated dust (DD1 + DD2 + DD3)



Shown is ratio of CAMS n.r.t. aerosols to CAMS climatology (gray means n.r.t. below climatology).

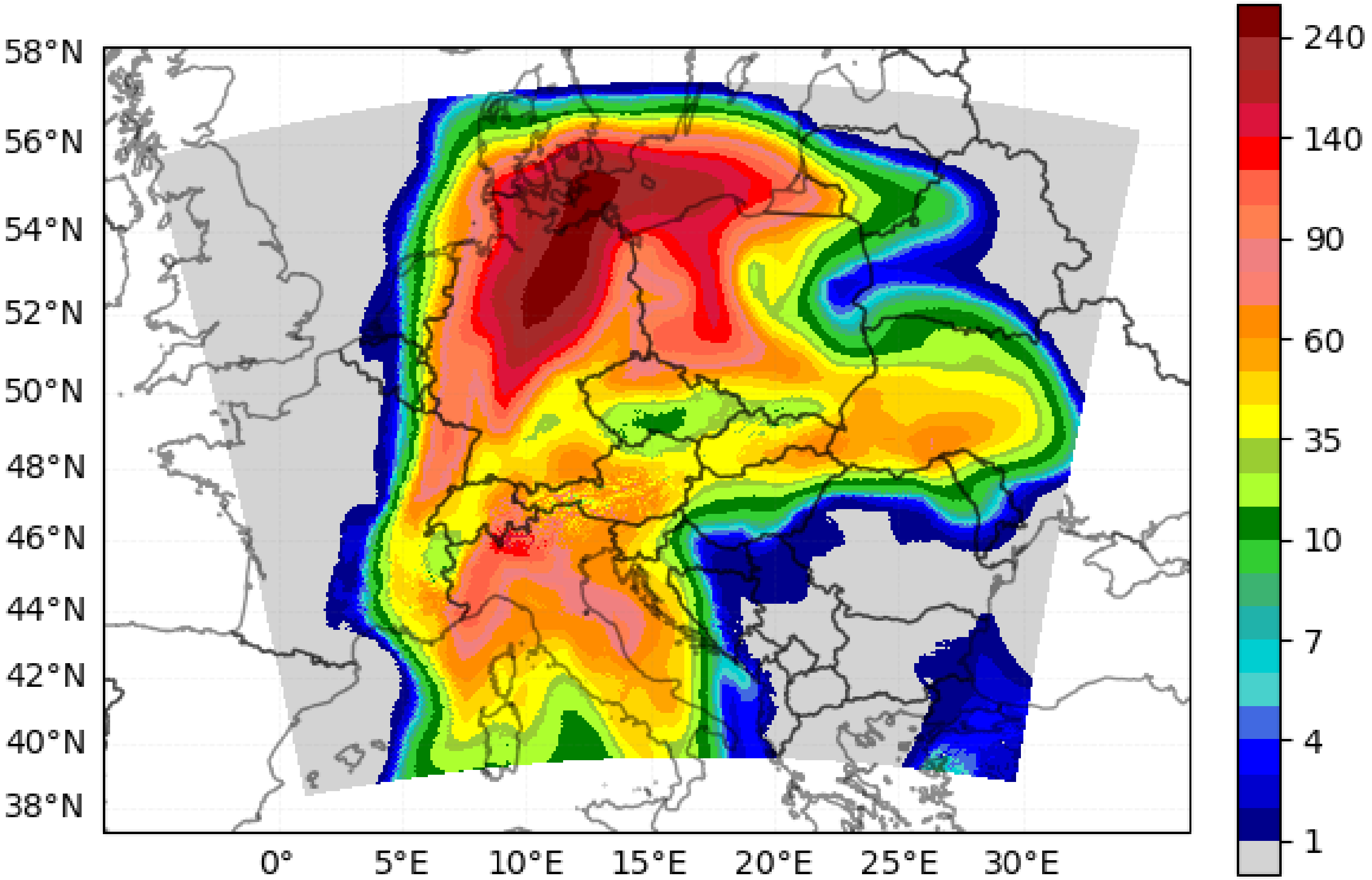
MSG 24h microphysics



Colors: red – vertically extensive clouds; beige – low/medium clouds; pink – dust.

Intrusion of Saharan dust (30 March 2024, 12 UTC)

vertically integrated dust (DD1 + DD2 + DD3)



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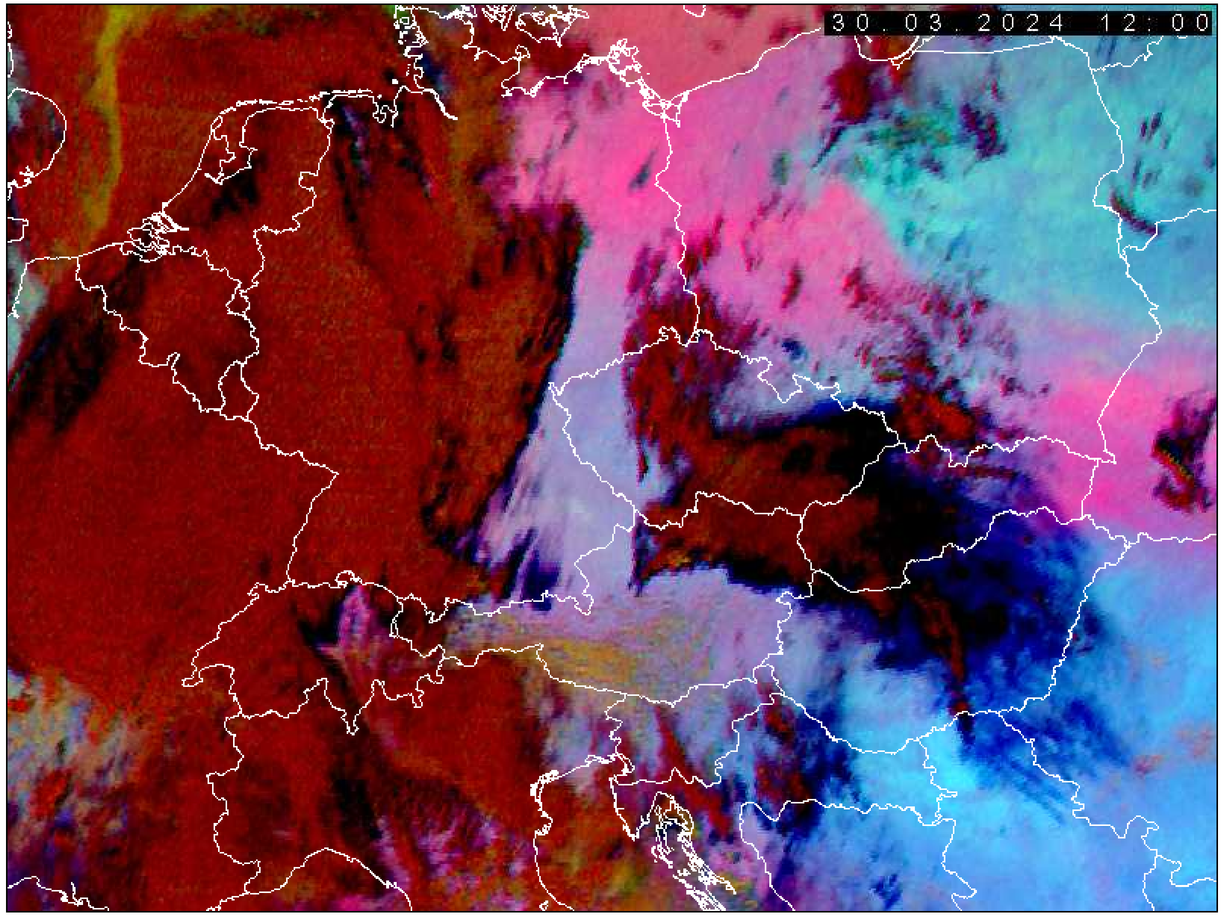
MSG 24h microphysics



Colors: red – vertically extensive clouds; beige – low/medium clouds; pink – dust.

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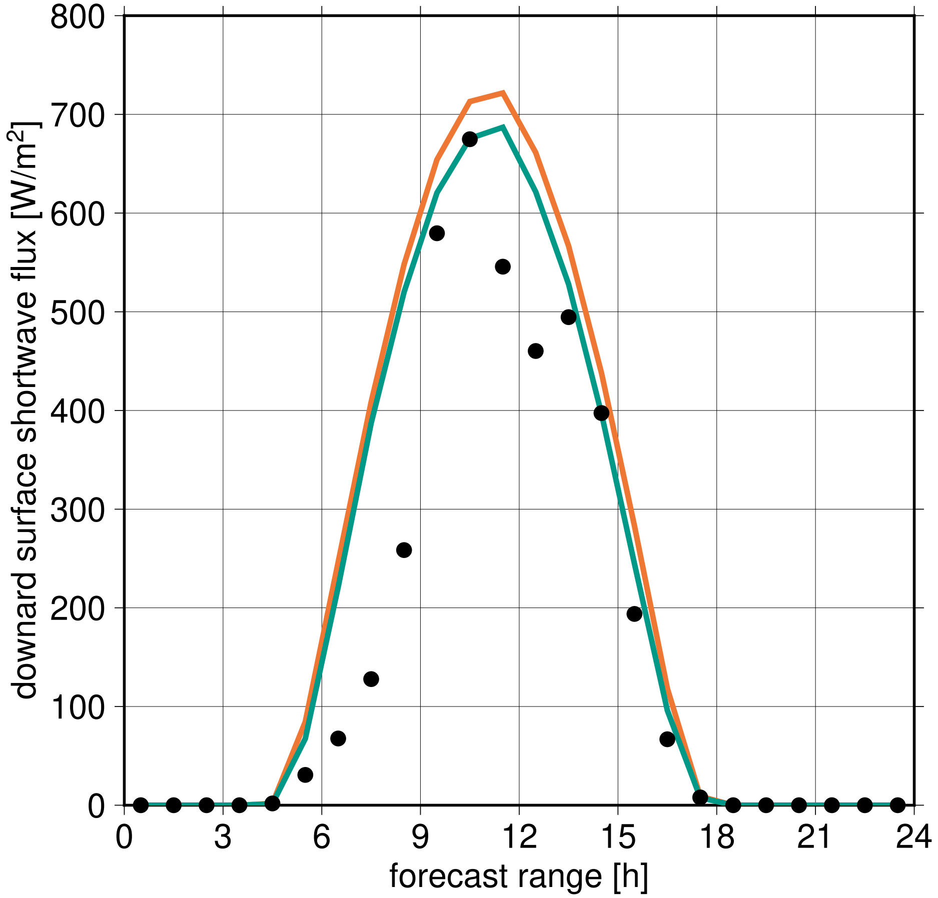
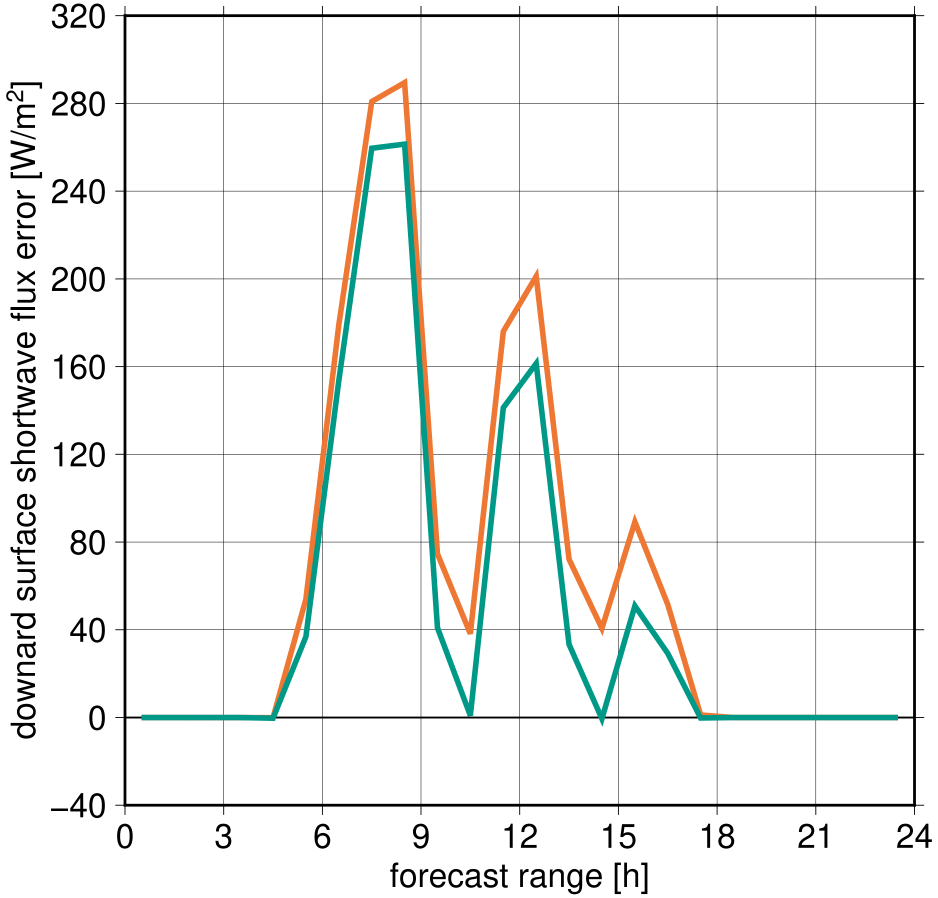
Aerosol impact on global radiation in dust case (30 March 2024)

global radiation, Prague



error of global radiation, Prague



background AOD:

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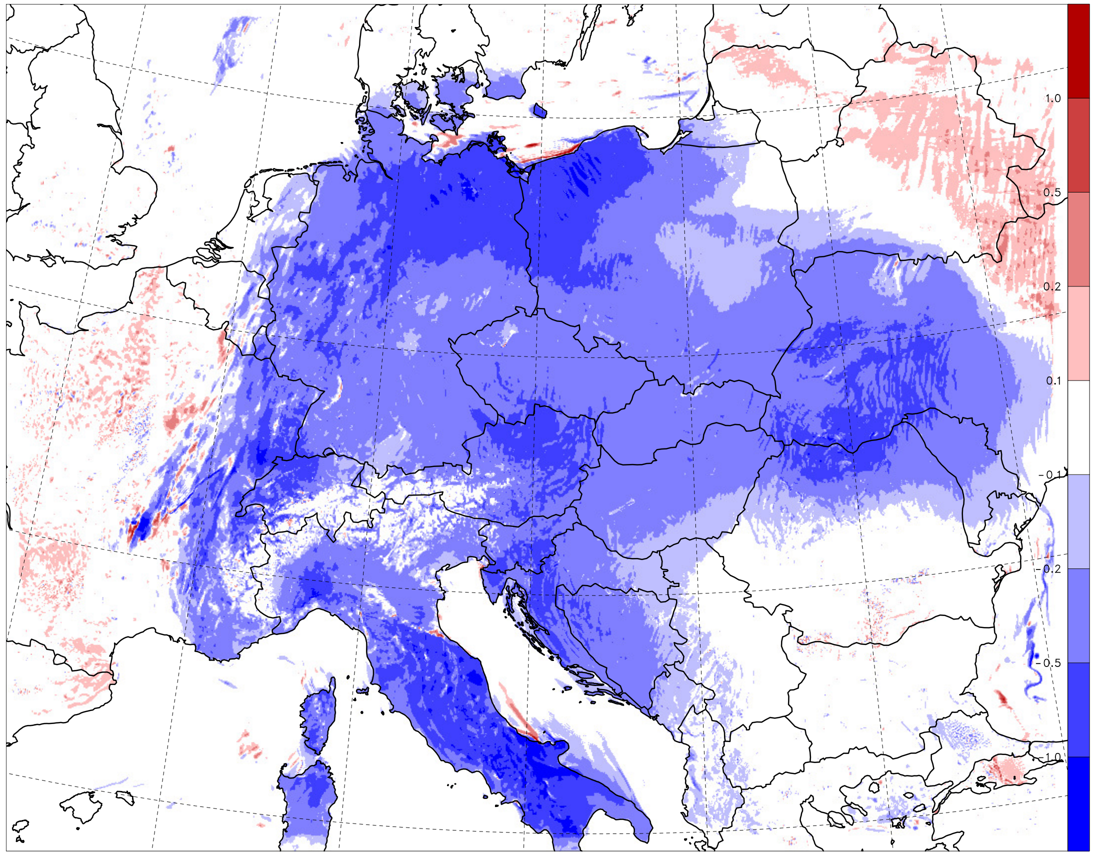
volcanic ashes = 0.007
(hardcoded)

0.082

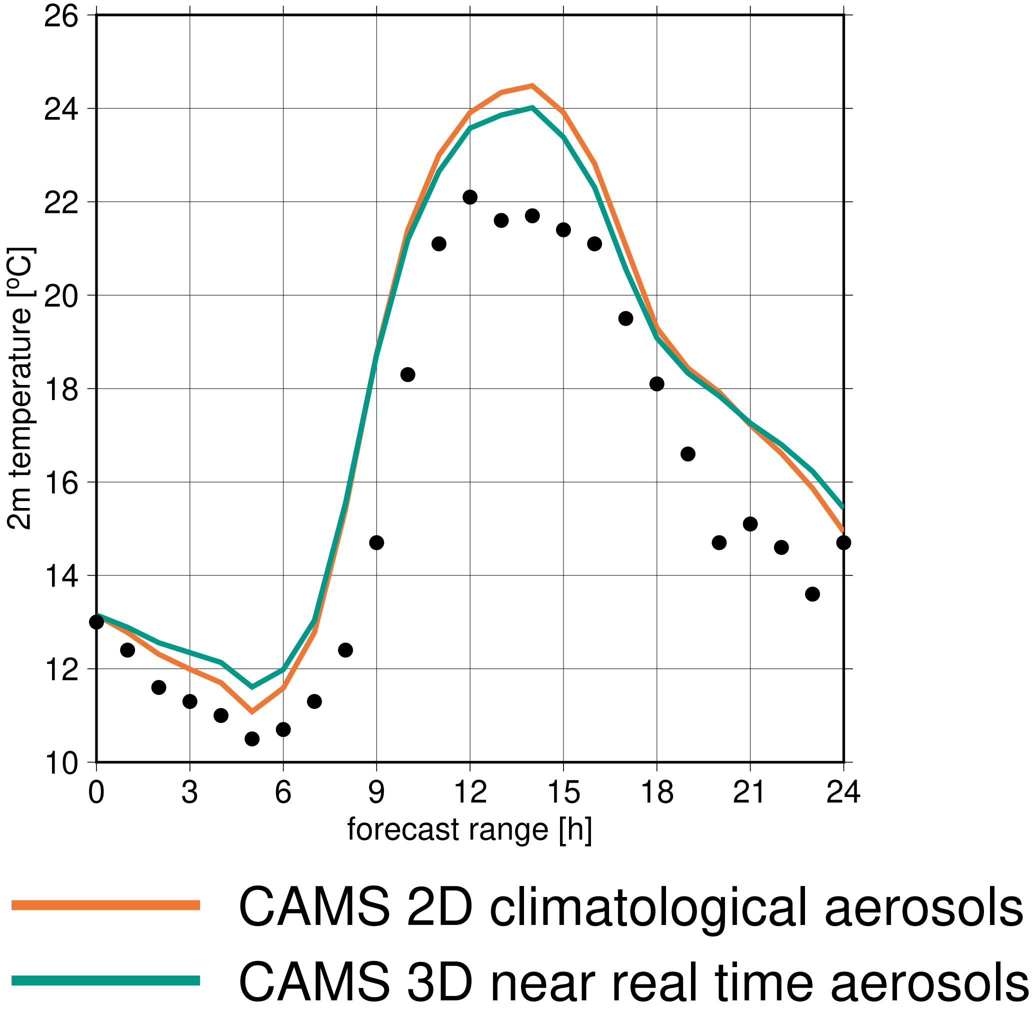
CAMS 2D climatological aerosols
CAMS 3D near real time aerosols

Aerosol impact on 2m temperature in dust case (30 March 2024)

T2m, CAMS 3D n.r.t. minus 2D climatology (12-hour forecast starting at 00 UTC)



T2m evolution, Prague (24-hour forecast starting at 00 UTC)



This time, **CAR** is more important than C**A**R!

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Towards NWP usage of CAMS aerosols at CHMI

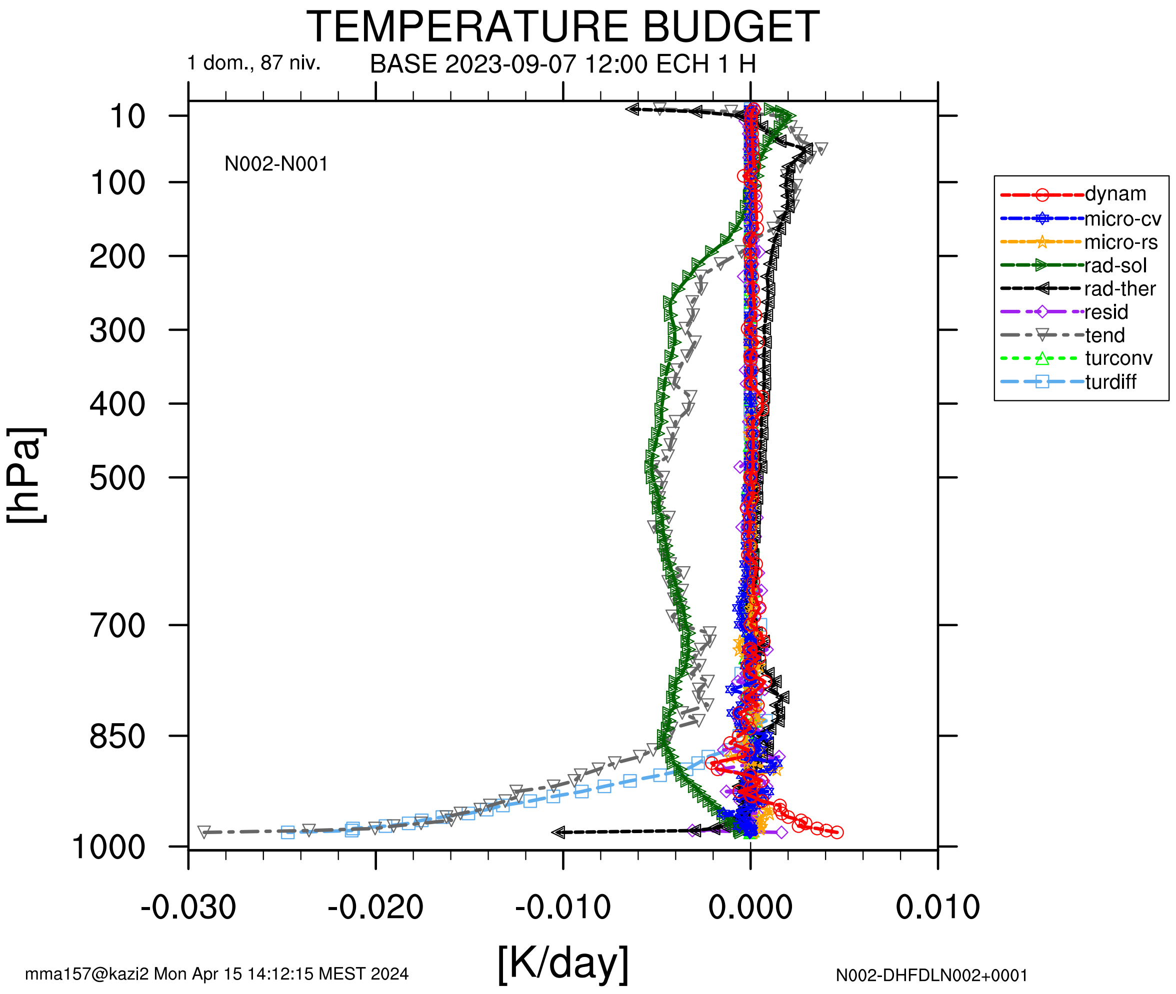
- We plan to update aerosols in our operational ALARO configuration in several steps:
  1) switch ACRANEB2 radiation to CAMS 2D climatological aerosols;
  2) switch ACRANEB2 radiation to CAMS n.r.t. aerosols;
  3) activate use of CAMS aerosols in ALARO microphysics.
- Step 1) is ready to be tested in e-suite.
- Step 2) should address logistic issues, and future link with microphysics:
  - advect 3D n.r.t. aerosol MMRs or reconstruct them regularly from 2D n.r.t. aerosol mass?
  - combine n.r.t. dust with climatological treatment of remaining aerosol types?
- Step 3) is covered by ongoing PhD of David Němec, devoted to development of two-moment ALARO microphysics. Aerosols in microphysics can be used with various levels of complexity.

Usage of external aerosols in ALARO-Climate runs

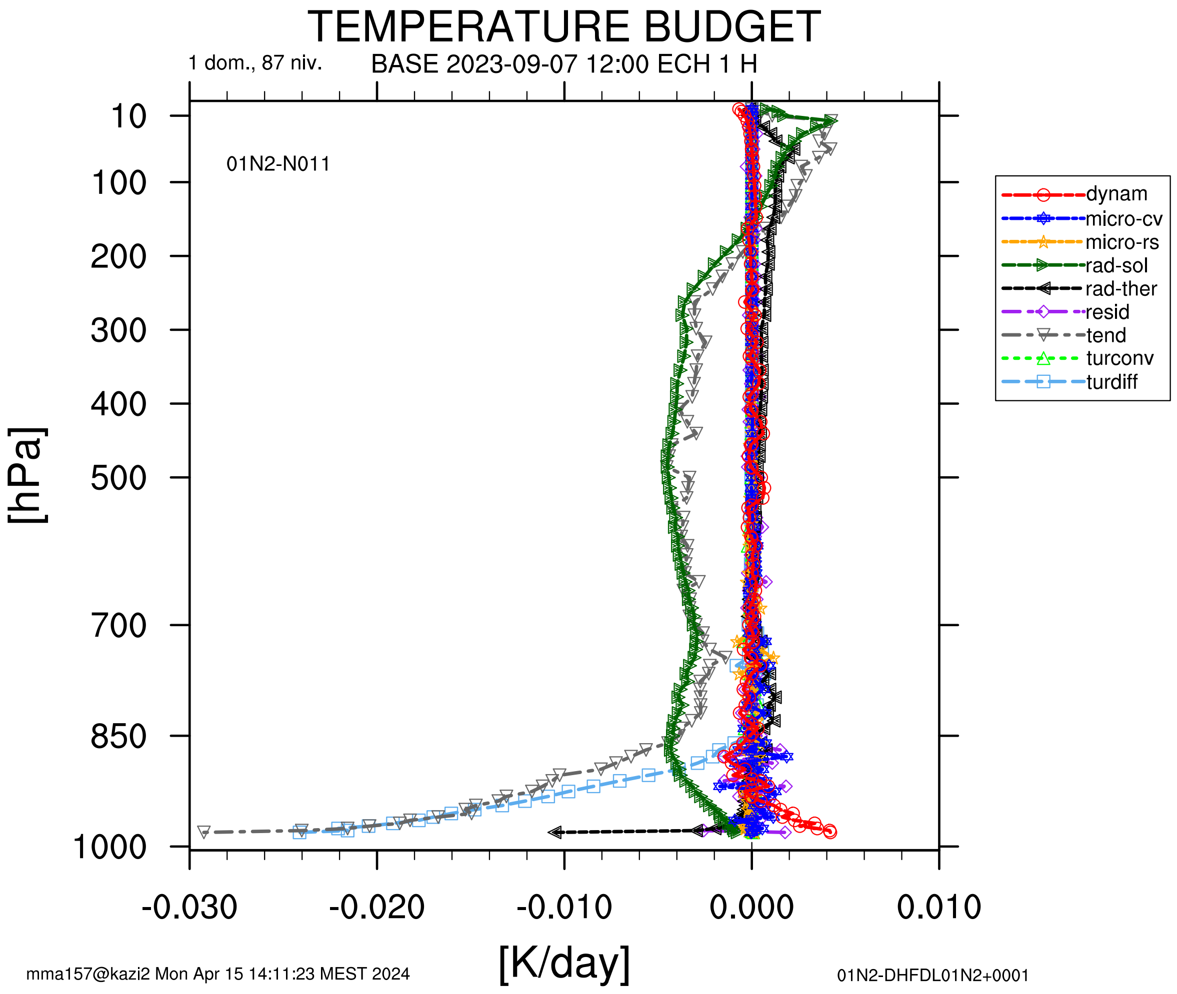
- First set of ALARO-Climate simulations at CHMI was run with present day aerosols and ozone.
- Driving system CNRM-ESM2-1 contains interactive aerosols and chemistry, providing:
  - 3D MMRs of basic 11 CAMS aerosol types;
  - historical stratospheric volcanic sulfates given as Tegen total AOD at 550 nm;
  - 3D MMRs of ozone.
- Thanks to CAR developments, 3D aerosol MMRs can enter ALARO-Climate.
- CNRM-ESM2-1 uses different size bins than CAMS $\Rightarrow$ optical properties of the sea salt and the desert dust must be adjusted!
- Intended strategy is to update 3D aerosols & ozone with 10-day frequency, with no advection. **Pros:** reduced download size & CPU time; no 2D $\rightarrow$ 3D conversion. **Cons:** jumpy evolution.

Obtaining CAMS equivalent of Tegen stratospheric volcanic sulfates

Response to Tegen volcanic sulfates (SURFAEROS.VOLCAN, $\delta_{550} = 0.01$)



Response via CAMS ammonium sulfate SU ($u = 1.08 \times 10^{-6}\,\mathrm{kg/m^2}$, $k^{\mathrm{ext}}_{550} = 9230\,\mathrm{m^2/kg}$)



Conclusions

- Radiation part of CAR developments is roughly finished:
  - minor code modifications are still foreseen;
  - inspection of aerosol backgrounds is needed.
- Advection of 14 CAMS n.r.t. aerosols can increase cost of ALARO-1 integration by up to 30%, while the use of 11 CAMS 2D climatological aerosols is for free.
- CAMS aerosols can be used in multiple ways, users have to find a reasonable compromise between complexity and efficiency fitting their needs.
- Impact of some simplifications still has to be tested.
- Useful code and user information can be found in the physics stay reports on the RC LACE web page. Aerosol documentations by Ana Šljivić are going to be placed there as well.

Thank you for your attention

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