CAIIR Task 6: 2D Aerosol

Daniel Rieger | COSMO General Meeting | 09/2023

Overview

Equations & Tuning

Basic Equation

Prognostic equation for 2D AOD $\psi_j(x,y)$ (red: tuning parameters)

$$\frac{\partial \psi_j(x,y)}{\partial t} = \underbrace{\overline{\boldsymbol{v}_{H,j}} \nabla \psi_j(x,y)}_{\text{advection}} + \underbrace{S_{e,j} + S_{w,j}}_{\substack{\text{sources \& sinks} \\ \text{(emission, washout)}}} + \underbrace{f_{diff} \cdot \Delta \psi_j(x,y)}_{\text{artificial diffusion}} + \underbrace{\frac{\psi_{clim,j}(x,y) - \psi_j(x,y)}{\tau_{clim,j}}}_{\text{relaxation to climatology}}$$

Diffusion factor:

$f_{diff,dust} = f_{diff,so4} = 0.05$ and $f_{diff,bc} = f_{diff,oc} = f_{diff,seas} = 0.1$

Relaxation time scale:

$\tau_{clim,dust} = 8d$, $\tau_{clim,so4} = 7d$, $\tau_{clim,bc} = 10d$, $\tau_{clim,oc} = 14d$, $\tau_{clim,seas} = 3d$

Vertically averaged horizontal wind:

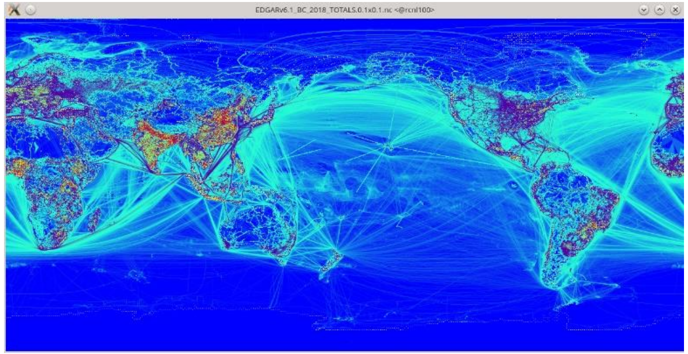
$\overline{\boldsymbol{v}_{H,dust}}$ (1500m - 6000m) and $\overline{\boldsymbol{v}_{H,so4}}$, $\overline{\boldsymbol{v}_{H,bc}}$, $\overline{\boldsymbol{v}_{H,oc}}$, $\overline{\boldsymbol{v}_{H,seas}}$ (500m -1500m)

Anthropogenic Aerosol

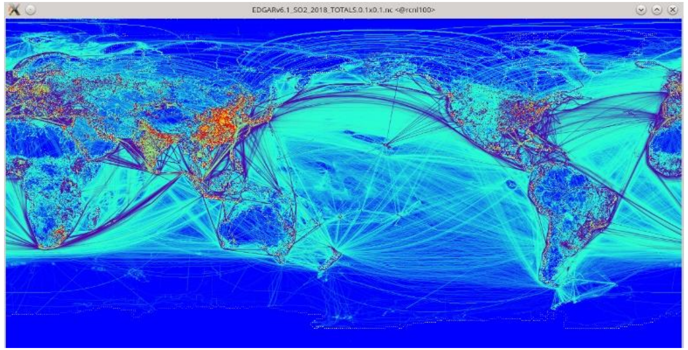
Black Carbon, Organic Carbon, Sulfate

Anthropogenic Emissions

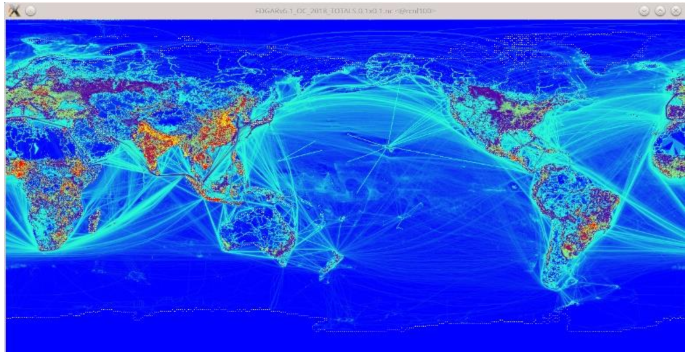
- Use emission dataset: **EDGAR**[1]
  - Emission Database for Global Atmospheric Research
  - Annual emissions for 2018
  - Black carbon, organic carbon, sulfate



Black Carbon



Sulfate

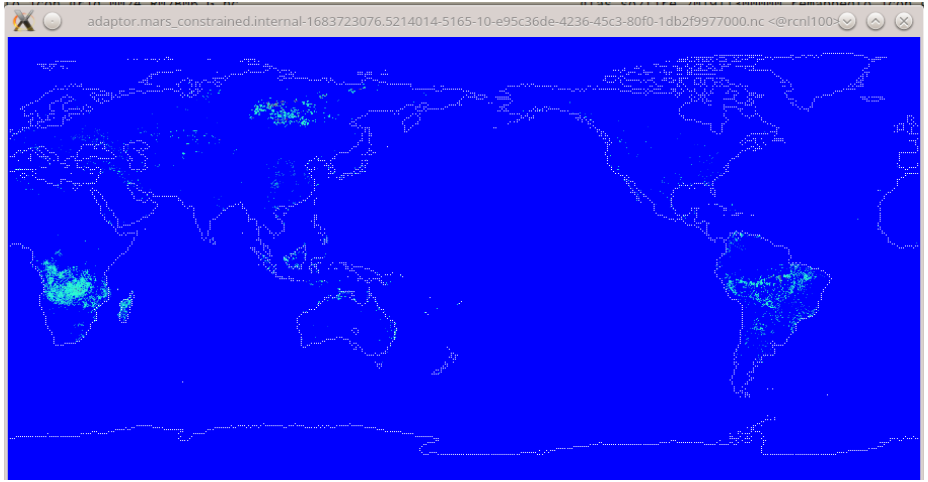


Organic Carbon

[1]***Source:*** *European Commission, Joint Research Centre (JRC)/Netherlands Environmental Assessment Agency (PBL) Emission Database for Global Atmospheric Research (EDGAR), http://edgar.jrc.ec.europe.eu*

Wildfire Emissions

- Use emission dataset: **GFAS** (Kaiser et al., 2012)
  - CAMS Global Fire Assimilation System (GFAS)
  - Daily emissions, near real-time: Guaranteed availability 7 UTC
  - Black carbon, organic carbon, sulfate



Wildfire black carbon emissions 11 Aug 2019

Generated using Copernicus Atmosphere Monitoring Service Information, 2023

Kaiser, J. W., Heil, A., Andreae, M. O., Benedetti, A., Chubarova, N., Jones, L., Morcrette, J.-J., Razinger, M., Schultz, M. G., Suttie, M., and van der Werf, G. R. (2012). Biomass burning emissions estimated with a global fire assimilation system based on observed fire radiative power. BG, 9:527-554.

Sulfate

Sulfate Nucleation

- Systematic **sulfate underestimation** in remote regions caused by
  - Different lifetime of sulfur dioxide (SO_2) and sulfate (SO_4^{2-})
  - Nucleation of SO_2 at low temperatures
- Simplified nucleation parameterization (red: tuning factors):

$$\boldsymbol{\tau_{SO4} = max(\tau_{SO4}, \tau_{SO4,max} \cdot f_\tau \cdot f_{ccrit} \cdot cos^{4}(\mu_0))}$$ with $\tau_{SO4,max} = 1$

  - Kerminen & Wexler (1994) add SO_2 above $c_{crit}(T, RH)$ to SO_4^{2-}
    This approach would require a gas-phase chemistry which is way to detailed for 2D-Aerosol!
  - As $c(SO_2)$ is not known for the 2D-aerosol, nucleation occurs if $c_{crit}(T, RH)$ exceeds a reference value f_{ccrit}

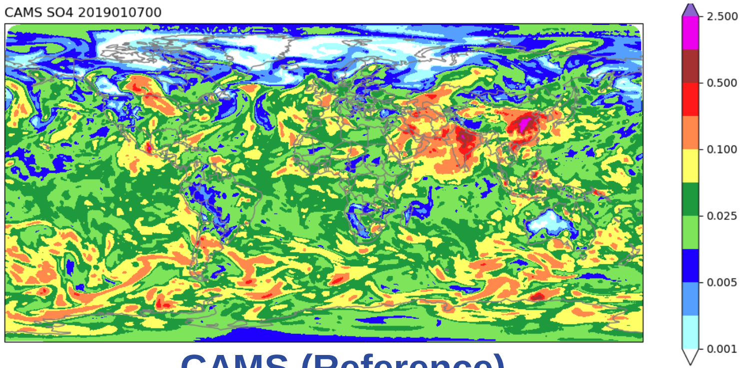
$$\boldsymbol{f_{ccrit} = min\left(1, max\left(0, \frac{c_{crit}(T,RH)}{c_{crit}(255,1)}\right)\right)}$$ with c_{crit} based on Kerminen & Wexler (1994)

  - Problem: the hypothetical SO_2 budget is not modified in this parameterization
  - Solution: limit this process by the current $c(SO_4^{2-})$ using optical depth τ_{SO4}:

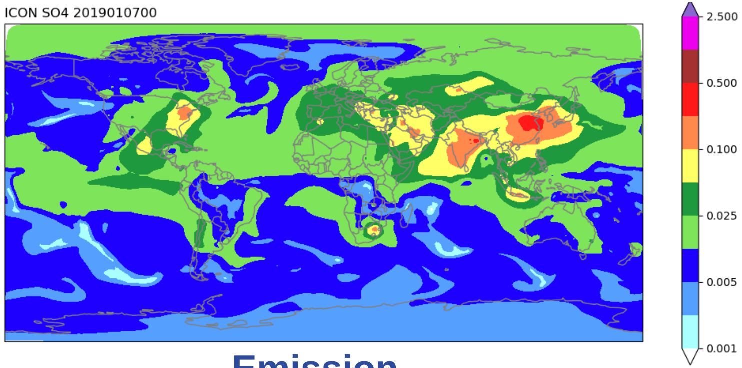
$\boldsymbol{f_\tau}$**: 2nd order polynomial** with $f_\tau\ (\tau_{SO4} = 0) = 1;\ f_\tau\ (\tau_{SO4} = 0.5) = 0$ and minimum at $\boldsymbol{\tau_{SO4} = 0.5}$

  - Formation of SO_4^{2-} involves photocatalytic reactions, solar zenith angle dependence $\boldsymbol{cos^{4}(\mu_0)}$

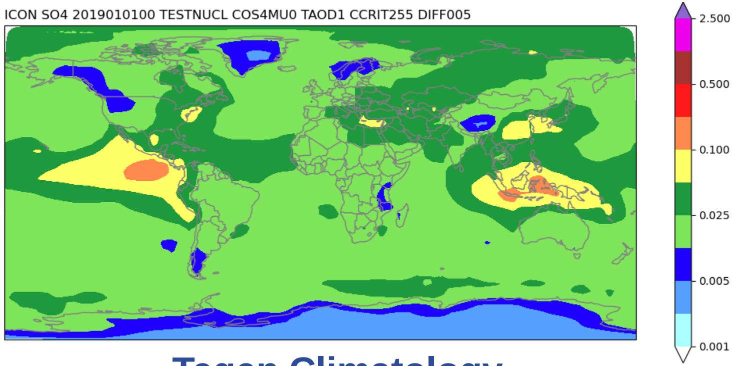
Sulfate Results



CAMS (Reference)

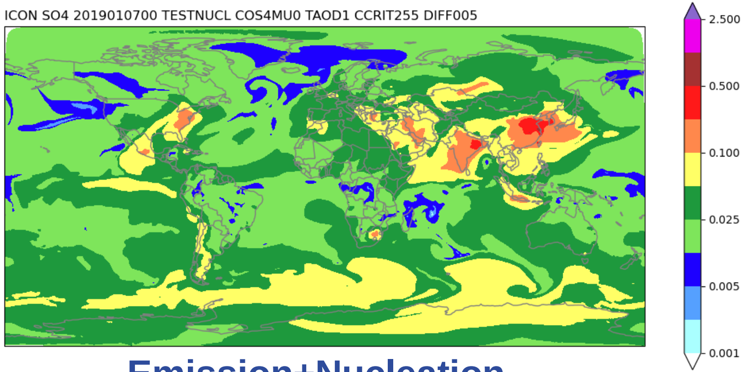


Emission



Tegen Climatology

(6 days earlier, but the differences are not significant…)



Emission+Nucleation

Verification Results

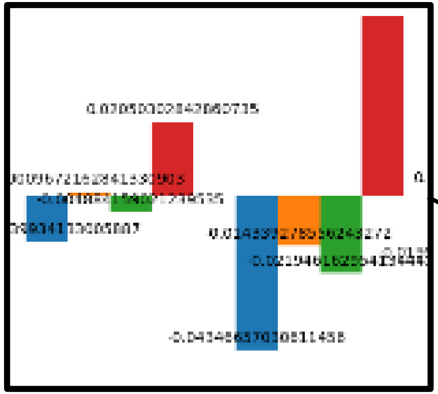
Verification AERONET

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

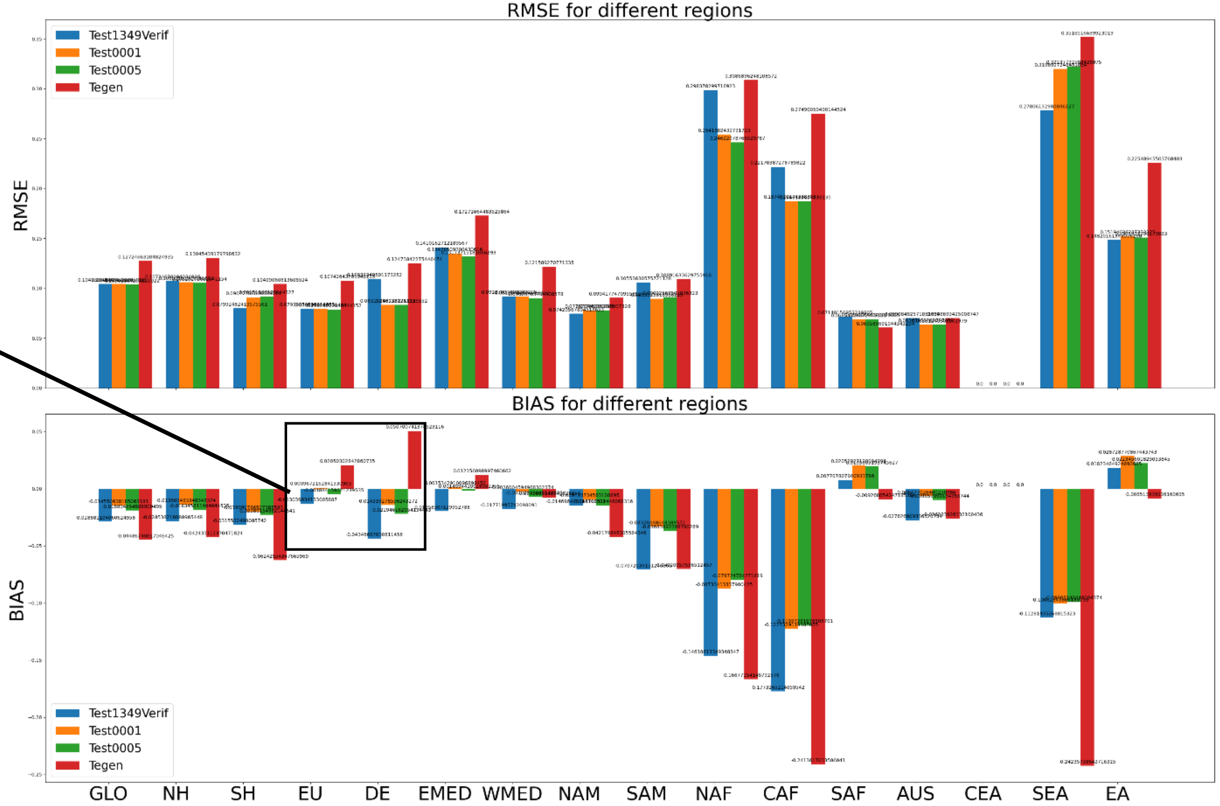
- R3B7N8 (ICON-Gl+Eu)
- 12-hrly forecasts
- 1 April 2022 – 15 June 2022
- Test1349 results used in the following slides for verification
- Test0001 and Test0005 aerosol looks even better, but verification is WIP
- 2D-Aerosol performs better than Tegen for all regions

Verification AERONET

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

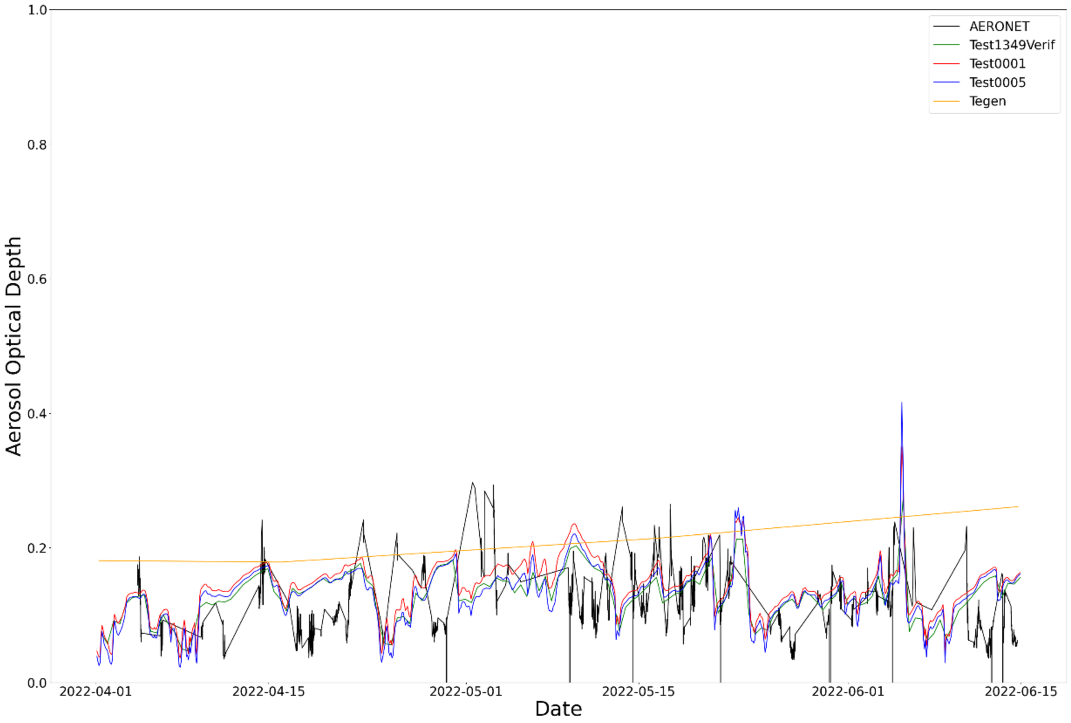


Test0001 (orange):
Nearly no bias for
Europe and Germany!



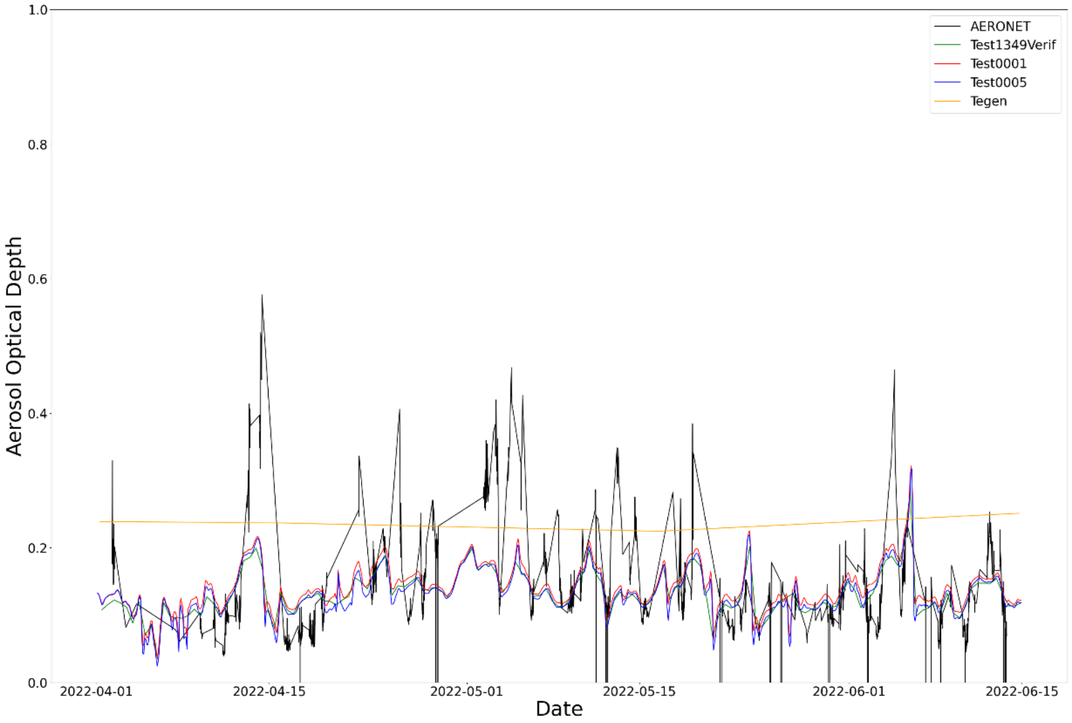
Hohenpeissenberg

HohenpeissenbergDWD, 47.801900°N, 11.011900°E

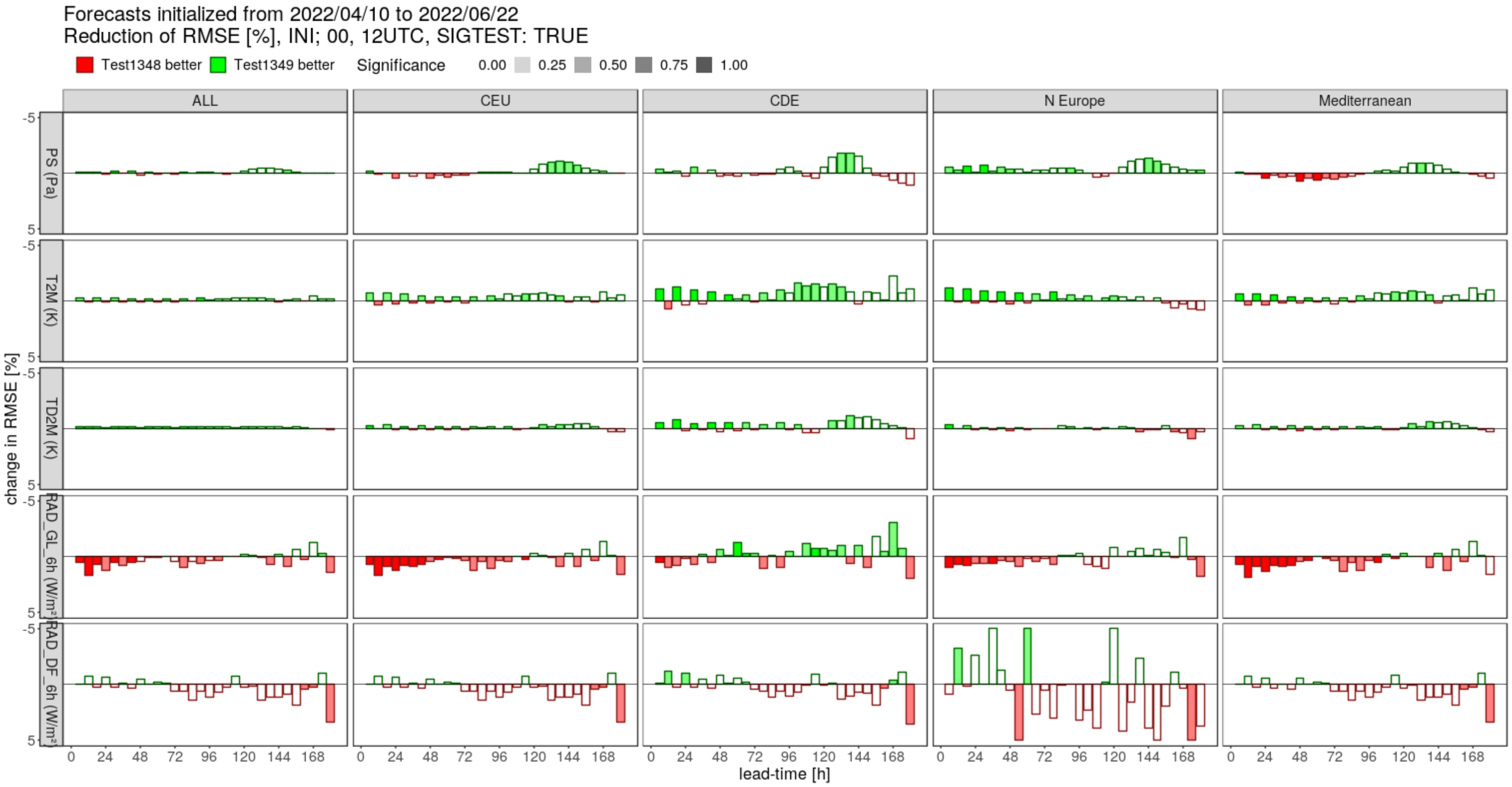


Lindenberg

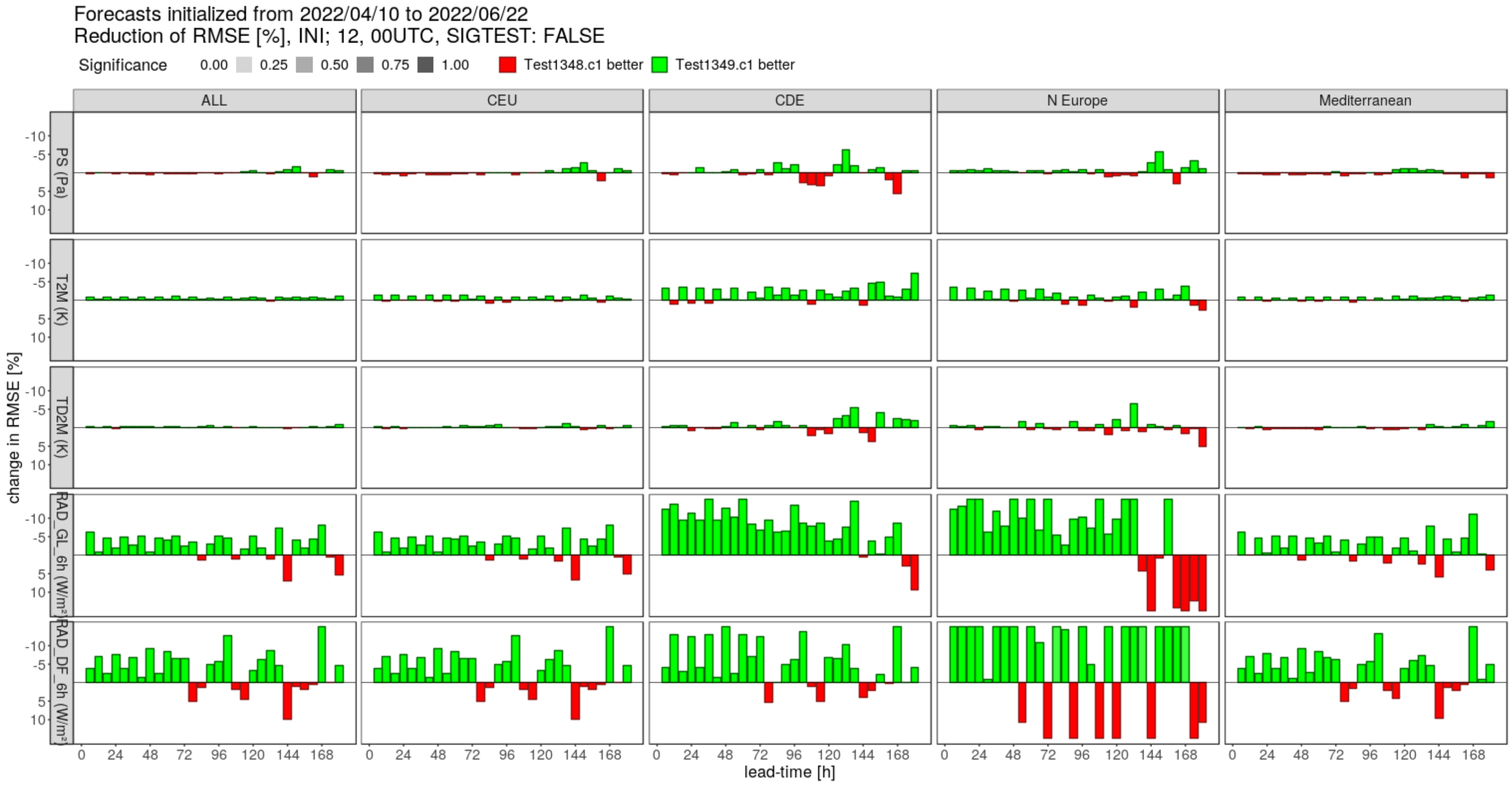
MetObs_Lindenberg, 52.209275°N, 14.120870°E



All Sky Synop RMSE

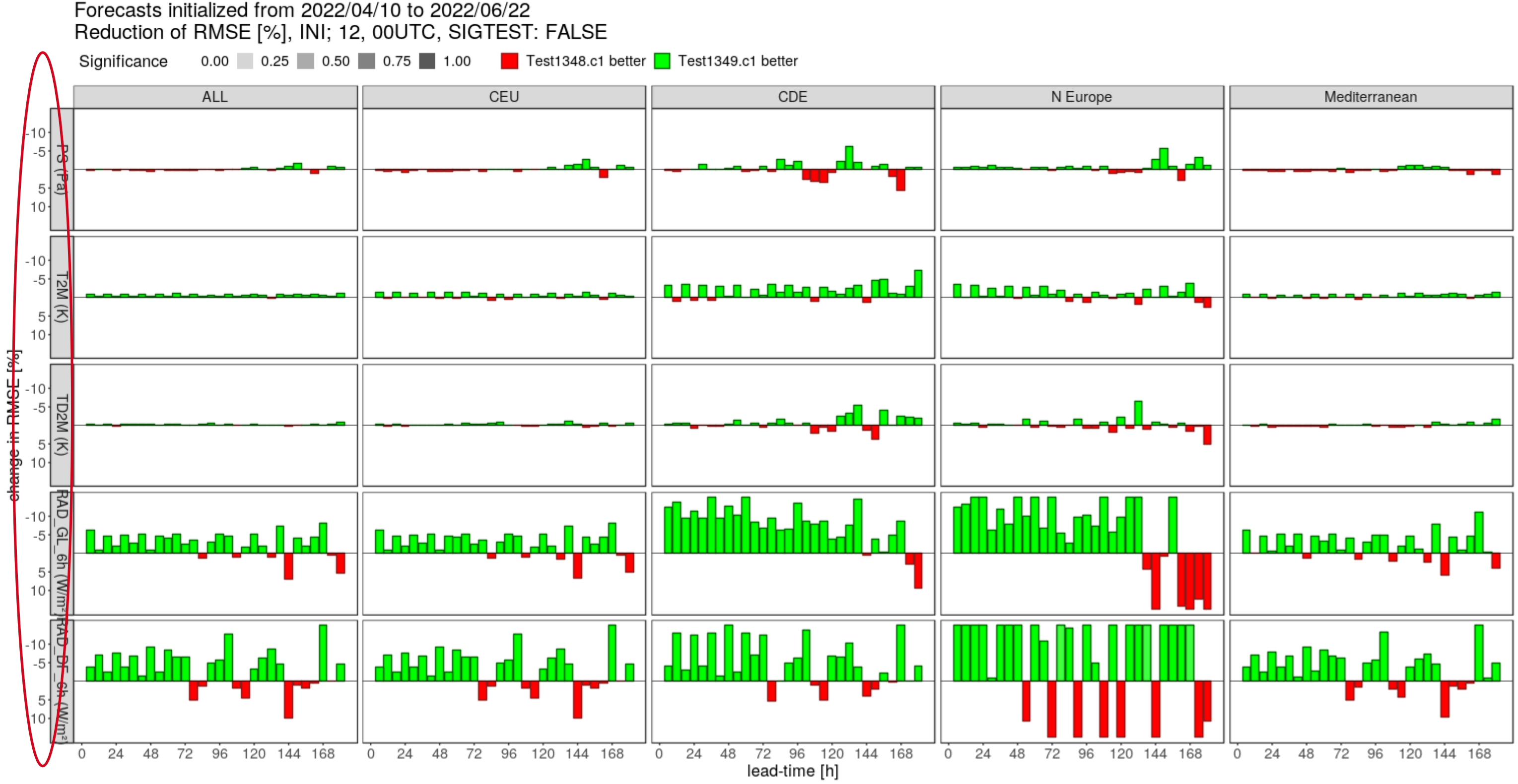


Clear Sky* Synop RMSE



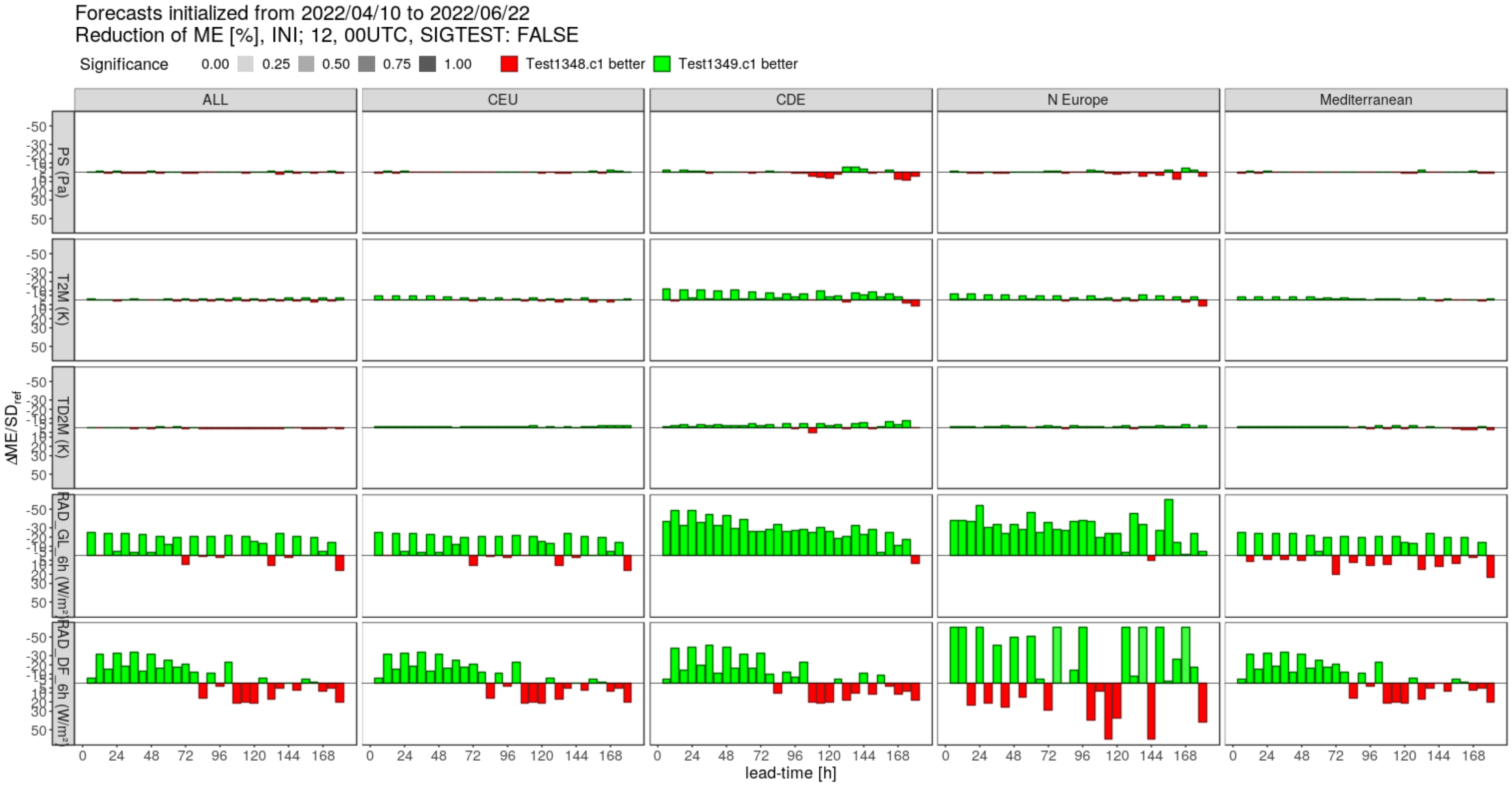
*CLCT(obs) = 0, CLCT(fc) <= 1/8

Clear Sky* Synop RMSE



*CLCT(obs) = 0, CLCT(fc) <= 1/8

Clear Sky* Synop BIAS



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Questions?