Karlsruher Institut für Technologie

meteo control
Energy & Weather Services

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Forecasting the reduction in photovoltaic power production during Saharan dust outbreaks

Vanessa Bachmann, Andrea Steiner, Jochen Förstner (DWD) & the PerduS-Team

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Outline

- Motivation
- Project PerduS
- Dust event 30/31 August 2017
- Sensitivity study concerning dust emission
- Quasi-operational application in DWD test-bench NUMEX

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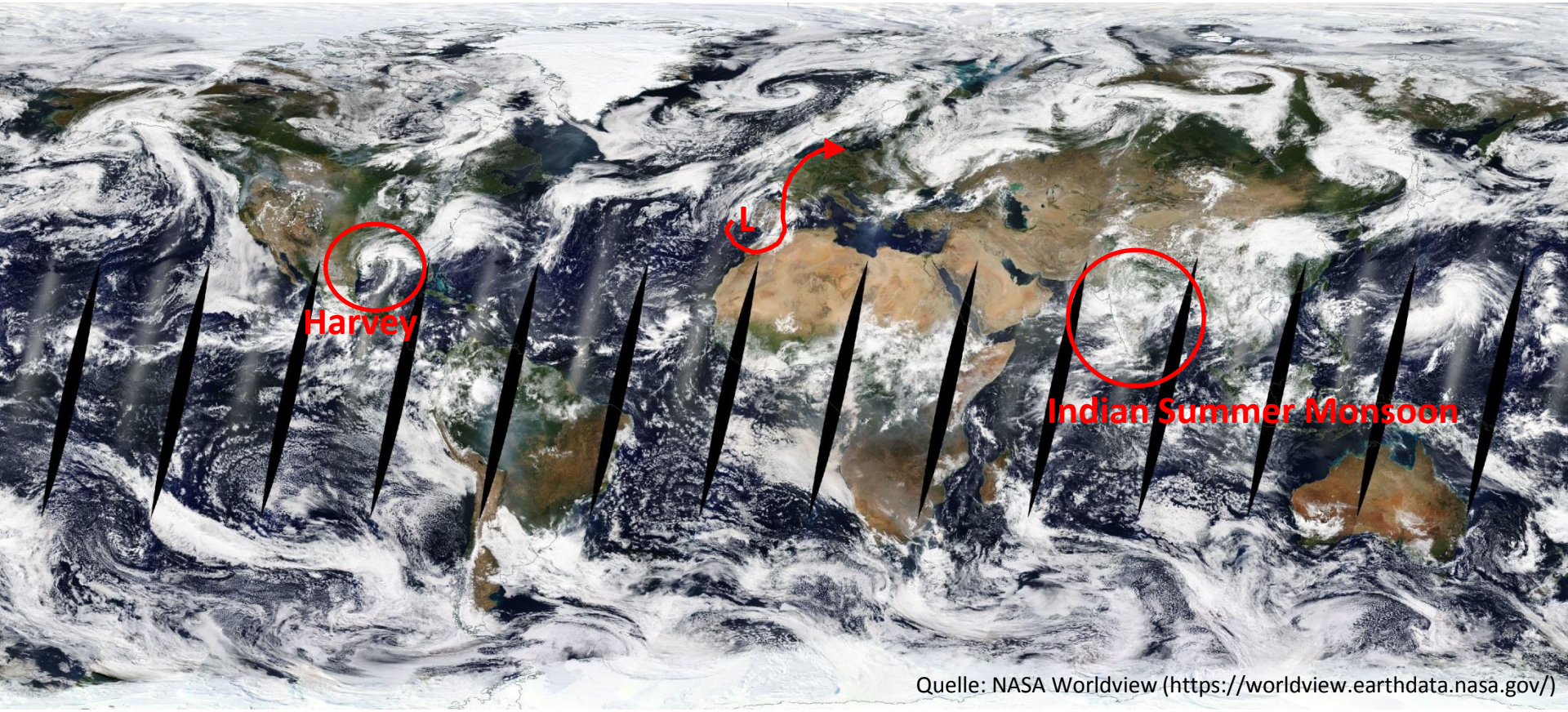
29 August 2017



Quelle: NASA Worldview (https://worldview.earthdata.nasa.gov/)

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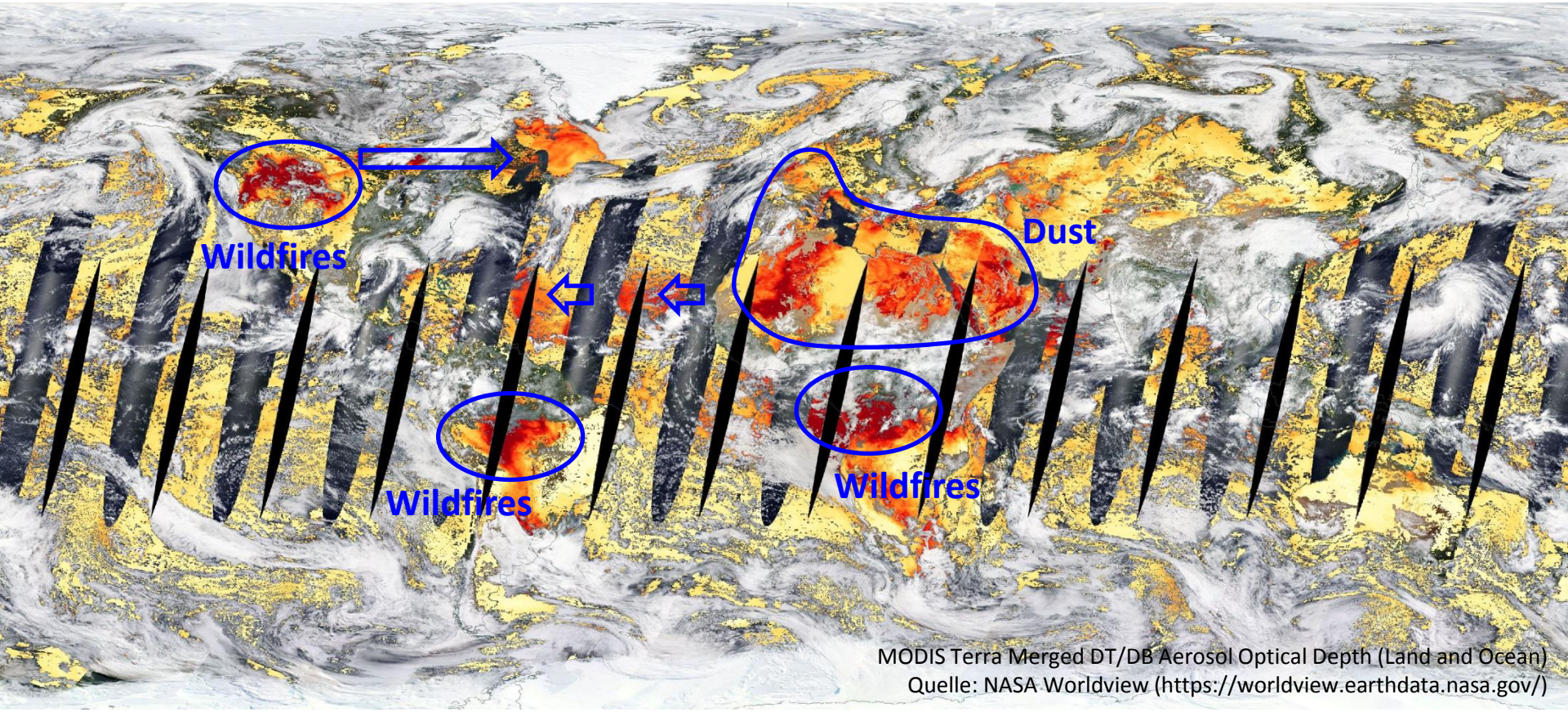

MODIS Terra Merged DT/DB Aerosol Optical Depth (Land and Ocean)
Quelle: NASA Worldview (https://worldview.earthdata.nasa.gov/)

Flentje et al., 2015: 5 – 15 Saharan Dust events/year at Hohenpeißenberg (1997 – 2013)

37.8 % Renewables in Germany, 8.4 % PV (Net power generation for public supply, 2017)

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Project Members

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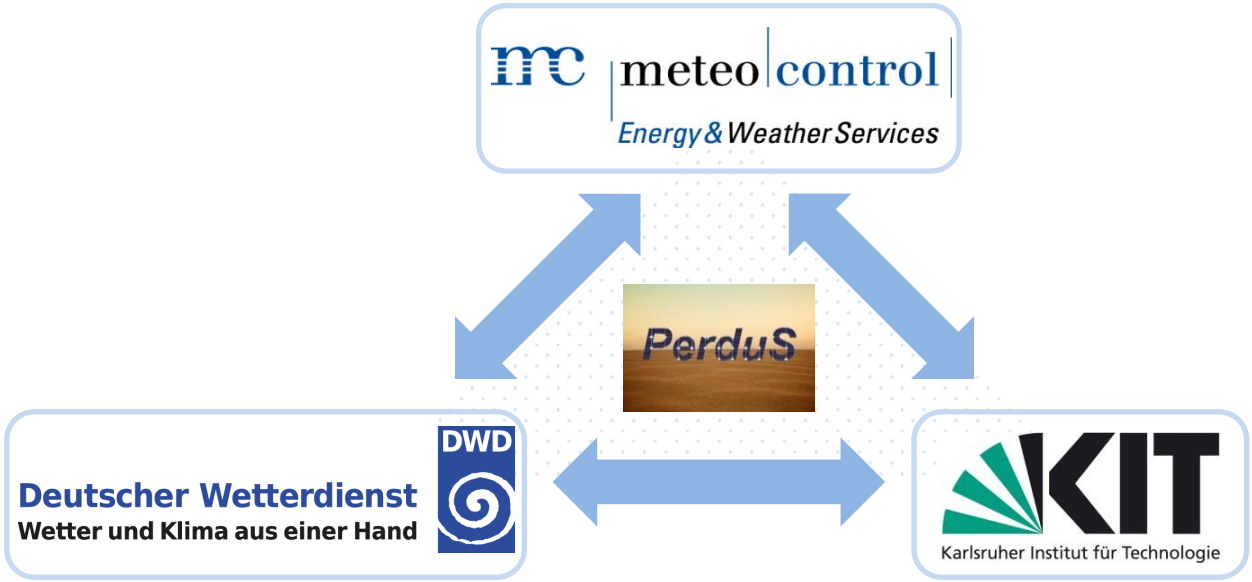
Federal Ministry
for Economic Affairs
and Energy



4 years: 01 March 2016 – 29 February 2020

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Project Goals

Main objective:

➔ Improvement of PV-power forecasts during Saharan dust outbreaks on a regional and national scale

Therefore:

➔ Use and improvement of the model system ICON-ART

- dust emission
- optical properties of mineral dust
- washout of aerosols

➔ High quality observations

➔ Consideration of polluted PV-panels and cleaning due to precipitation

➔ Quasi-operational application

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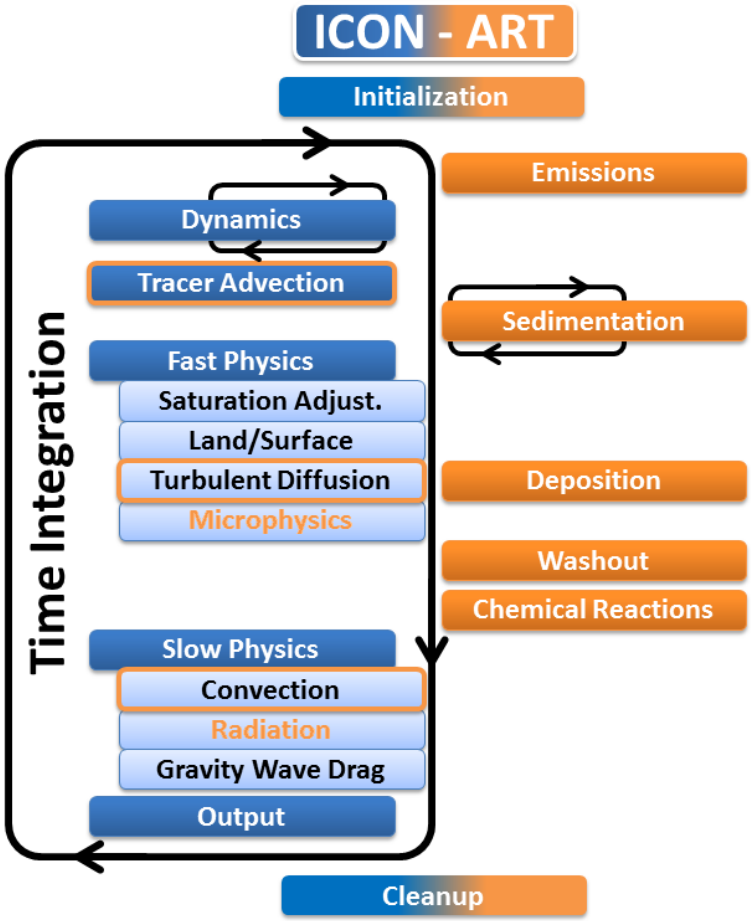
ICON and ART (Aerosols and Reactive Trace Gases)



Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-441
Manuscript under review for journal Atmos. Chem. Phys.
Discussion started: 21 June 2017
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Atmospheric Chemistry and Physics Discussions

Impact of the 4 April 2014 Saharan dust outbreak on the photovoltaic power generation in Germany

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→ see: https://www.atmos-chem-phys-discuss.net/acp-2017-441/

For ICON see Zängl et. al. 2015 For ICON-ART see Rieger et. al. 2015

Saharan dust event

30/31 August 2017

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Saharan dust event 30/31 August 2017

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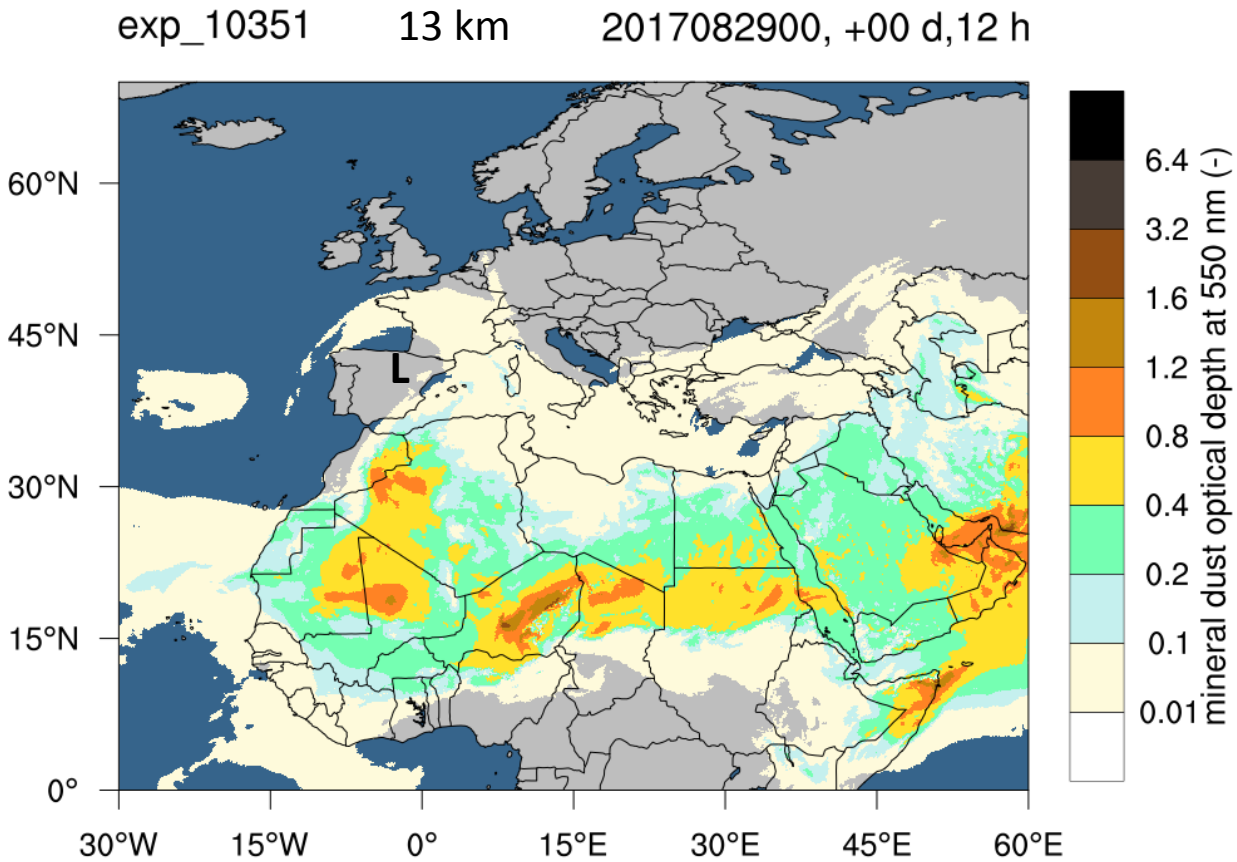
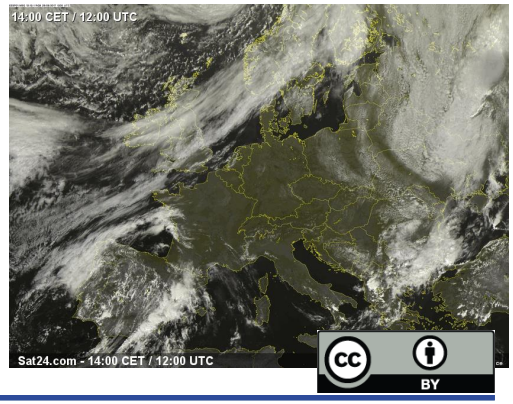


mean: 0.13, max: 2.27, std: 0.22 (area)

mean: 0.03, max: 2.27, std: 0.09 (global)

exp_10351:

- ICON-ART, 13 km global daily runs
- Dust is passed from previous run (-24h) since October 2016
- Aerosol-radiation interactions since 15 May 2017



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Saharan dust event 30/31 August 2017

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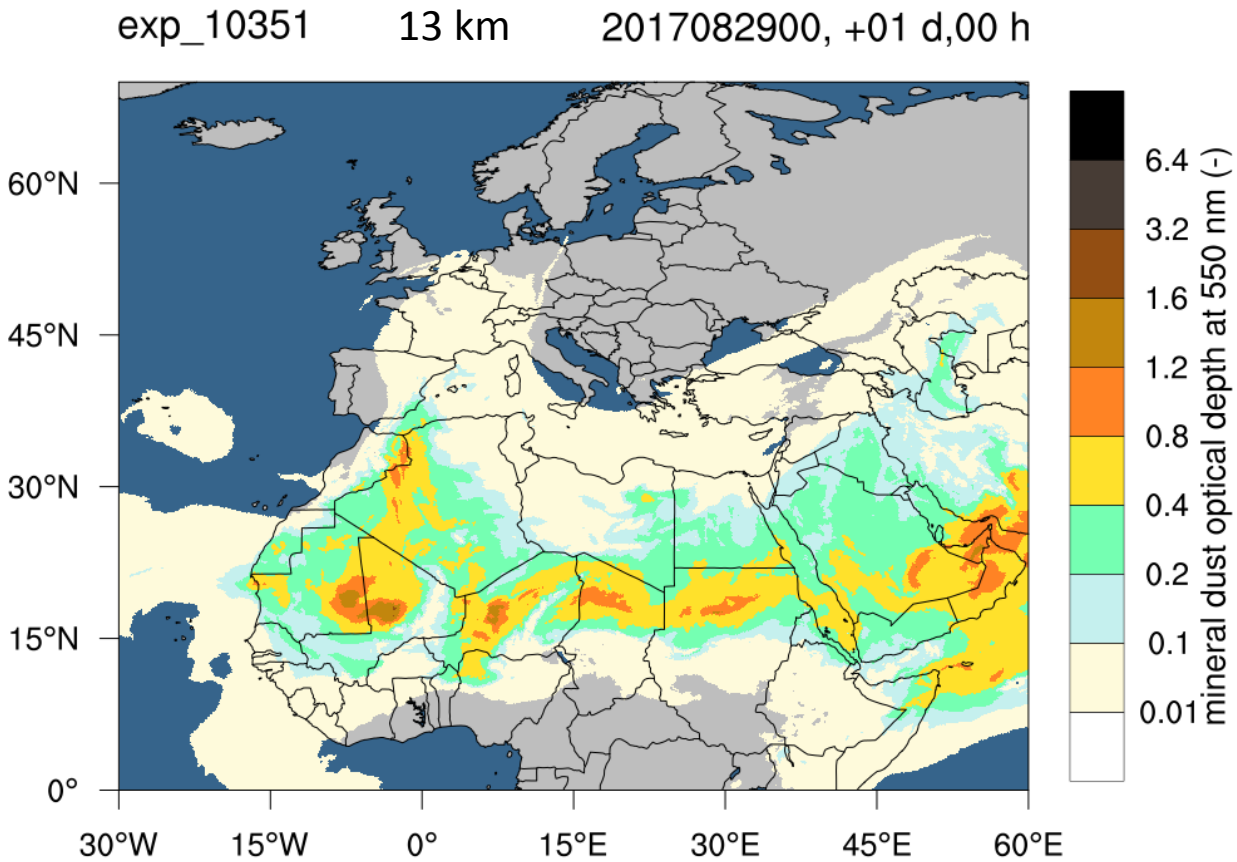

mean: 0.12, max: 1.68, std: 0.20 (area)

mean: 0.02, max: 2.63, std: 0.09 (global)

exp_10351:

- ICON-ART, 13 km global daily runs
- Dust is passed from previous run (-24h) since October 2016
- Aerosol-radiation interactions since 15 May 2017

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Saharan dust event 30/31 August 2017

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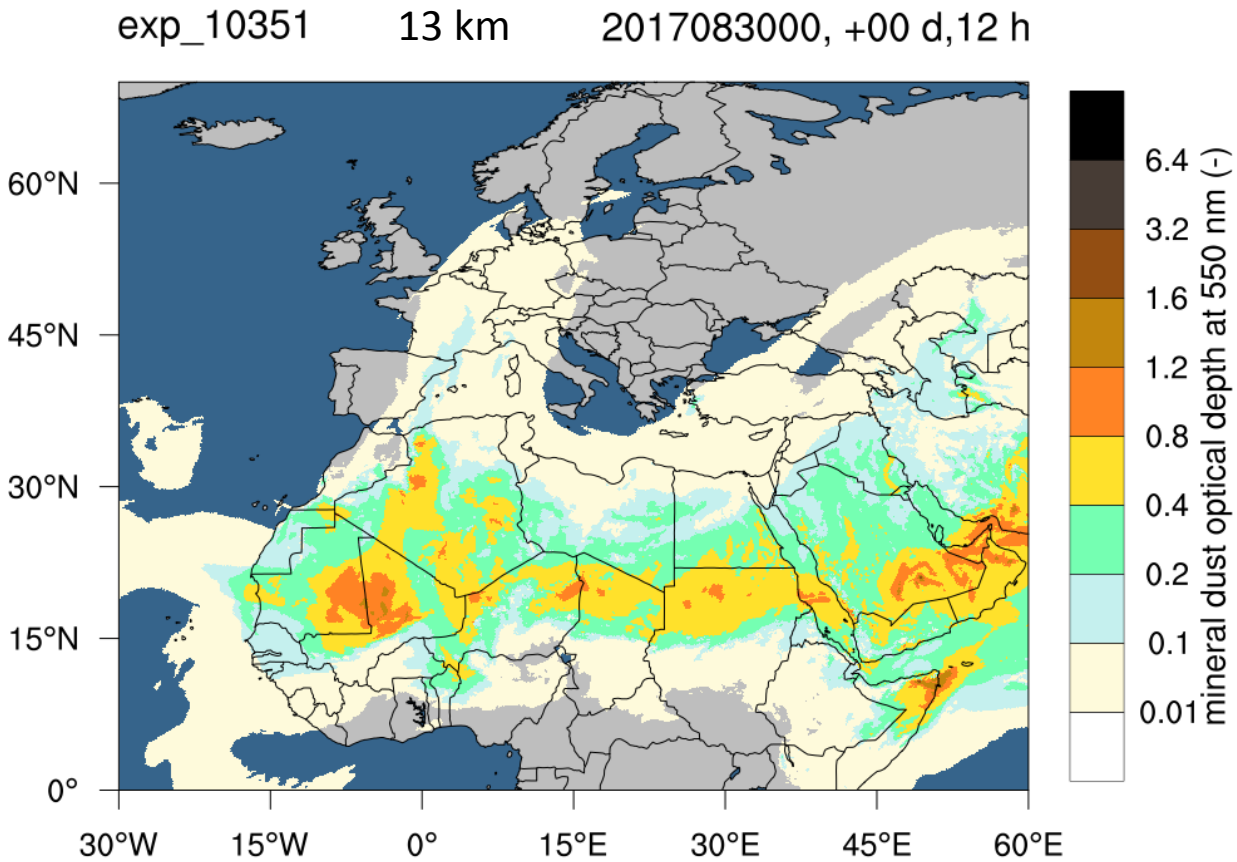
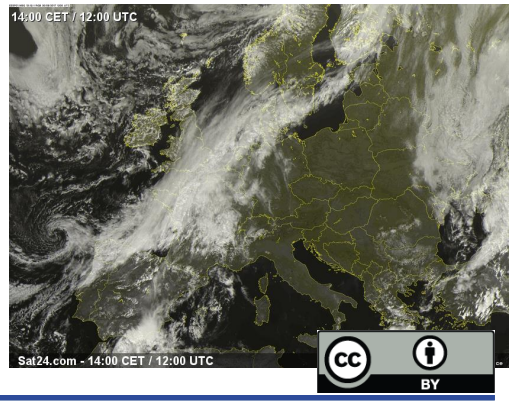


mean: 0.12, max: 1.89, std: 0.21 (area)

mean: 0.03, max: 1.89, std: 0.09 (global)

exp_10351:

- ICON-ART, 13 km global daily runs
- Dust is passed from previous run (-24h) since October 2016
- Aerosol-radiation interactions since 15 May 2017



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Saharan dust event 30/31 August 2017

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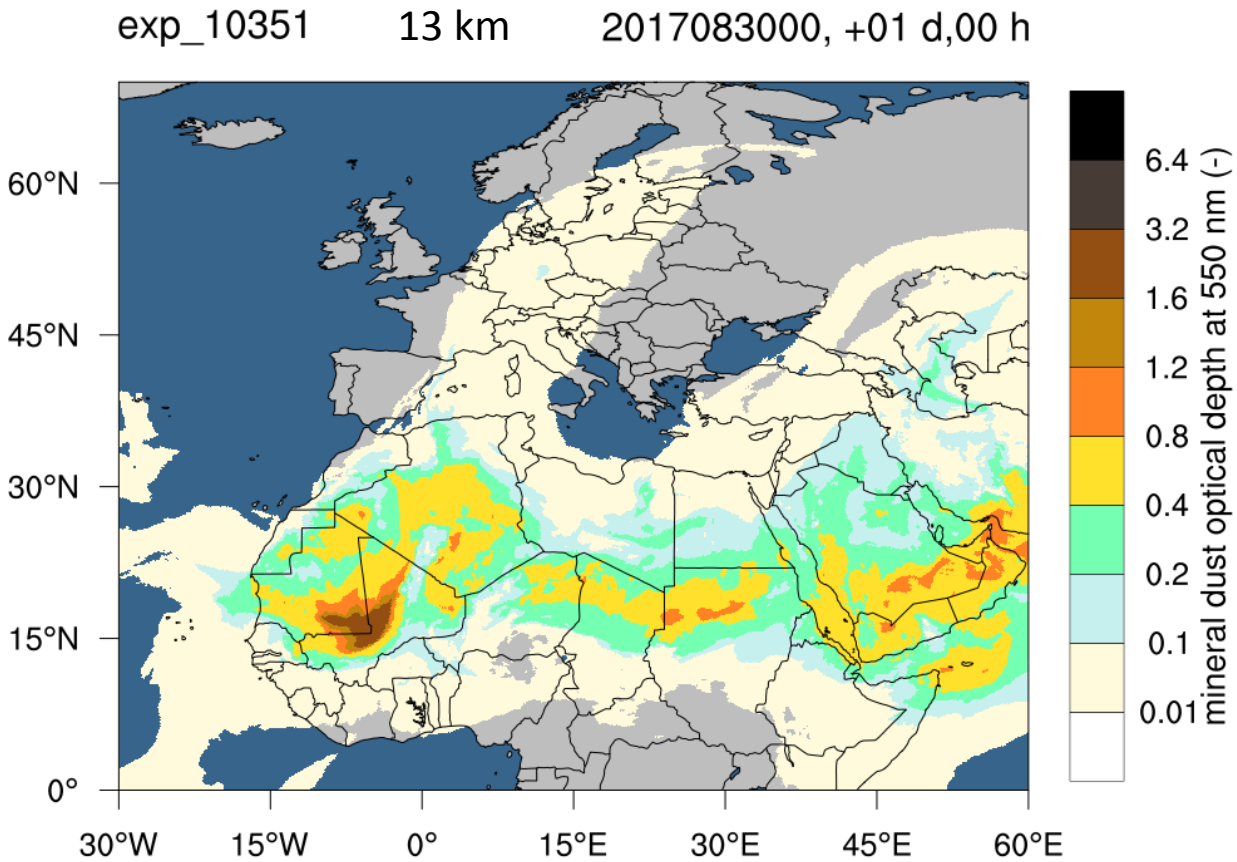

mean: 0.12, max: 2.93, std: 0.22 (area)

mean: 0.02, max: 2.93, std: 0.09 (global)

exp_10351:

- ICON-ART, 13 km global daily runs
- Dust is passed from previous run (-24h) since October 2016
- Aerosol-radiation interactions since 15 May 2017

How good is the forecast?

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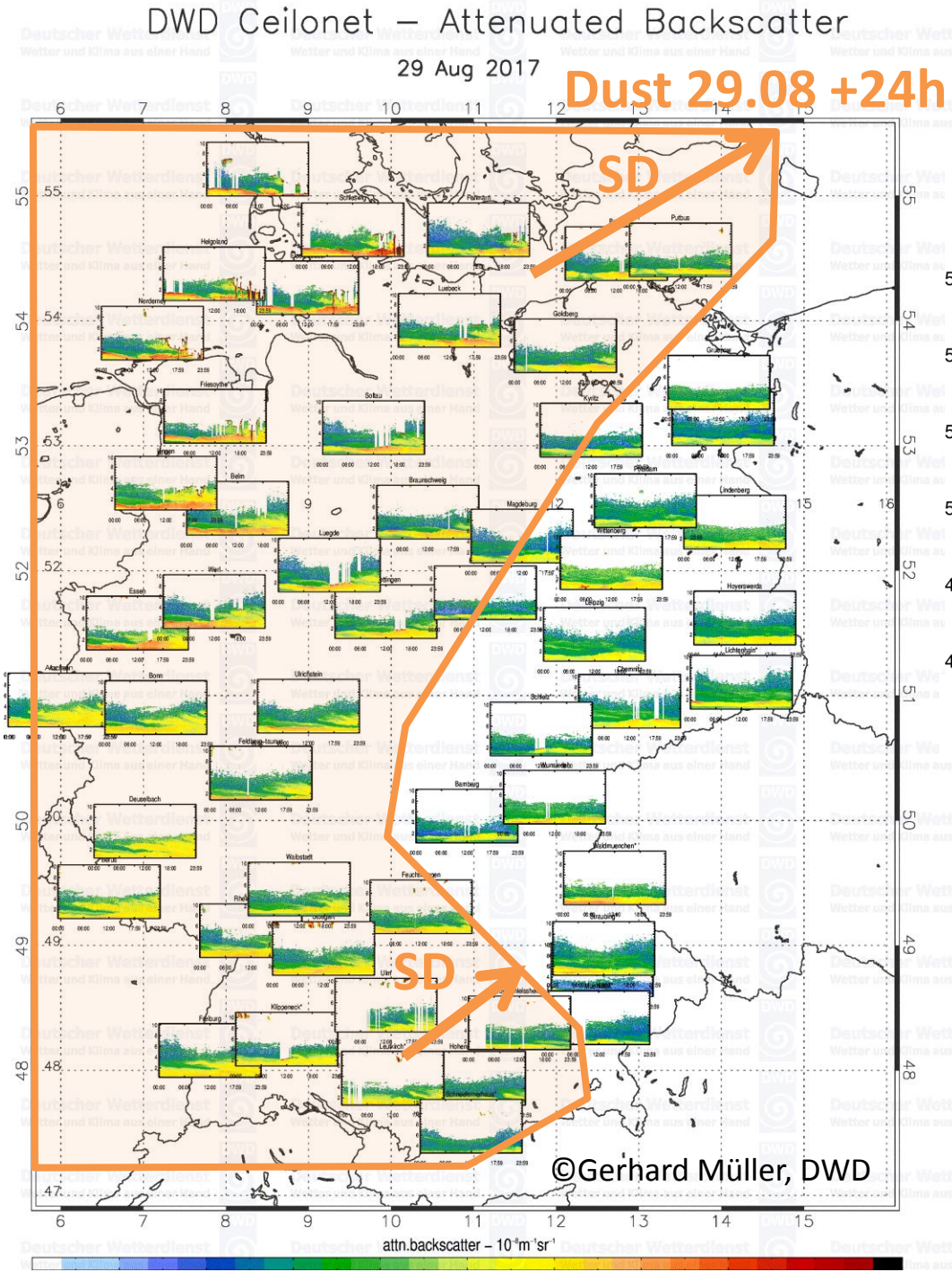

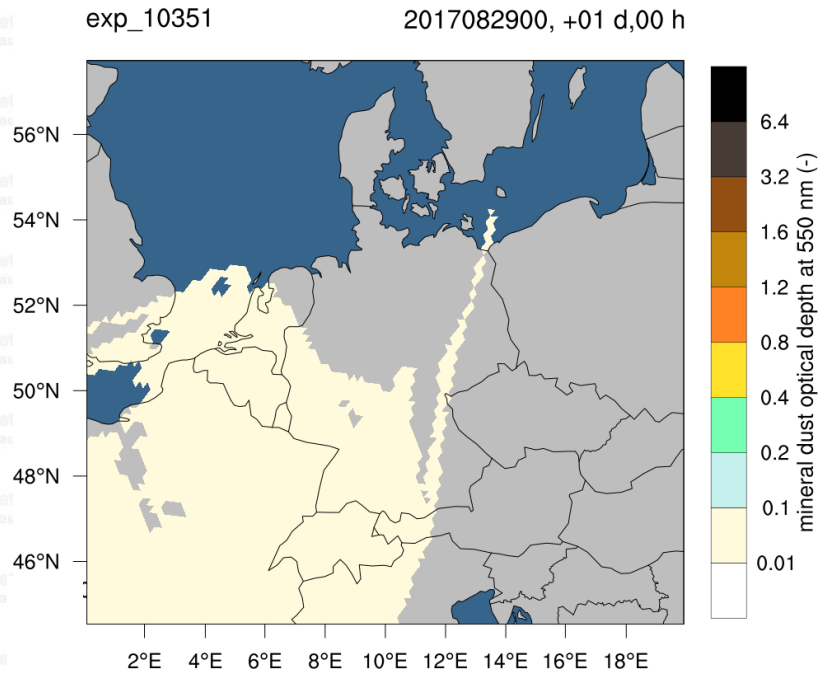

Too less dust in our forecast ?

Exp_10492: Modifications concerning aerosol washout:

- Impaction process
- washout due to grid scale and convective precipitation separately

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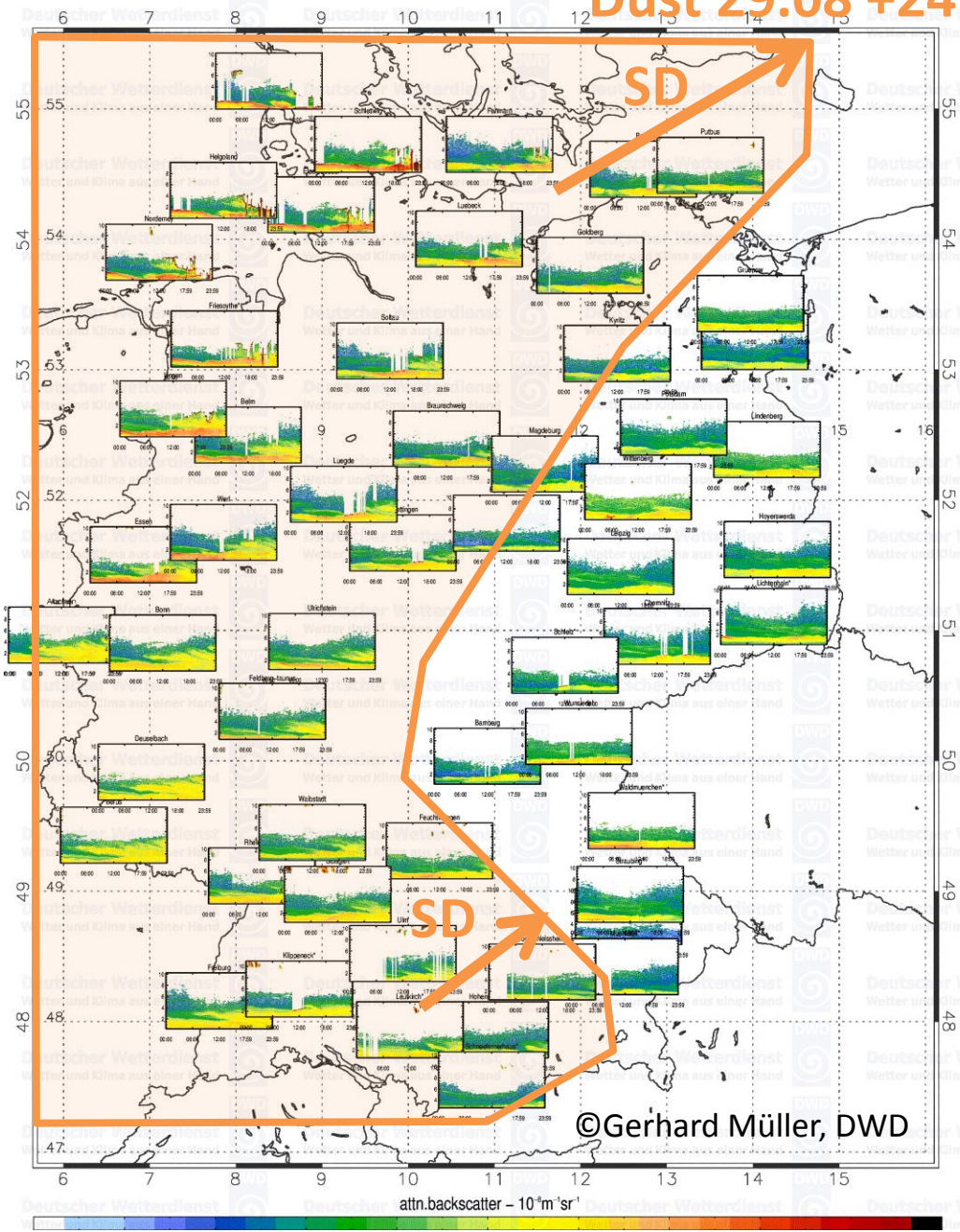
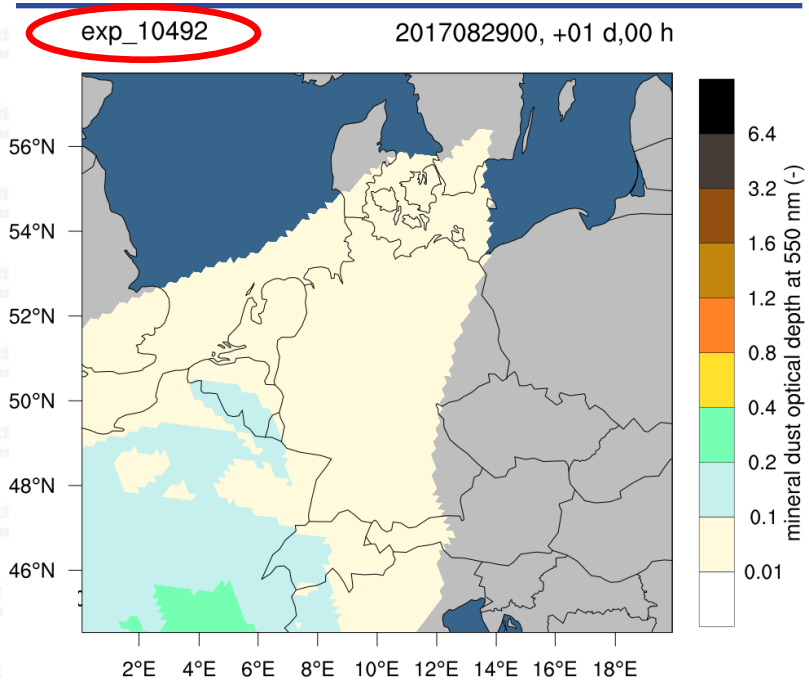
DWD Ceilonet – Attenuated Backscatter

29 Aug 2017

Dust 29.08 +24h



©Gerhard Müller, DWD



Satellite, AERONET

→ Now a little bit too much dust …

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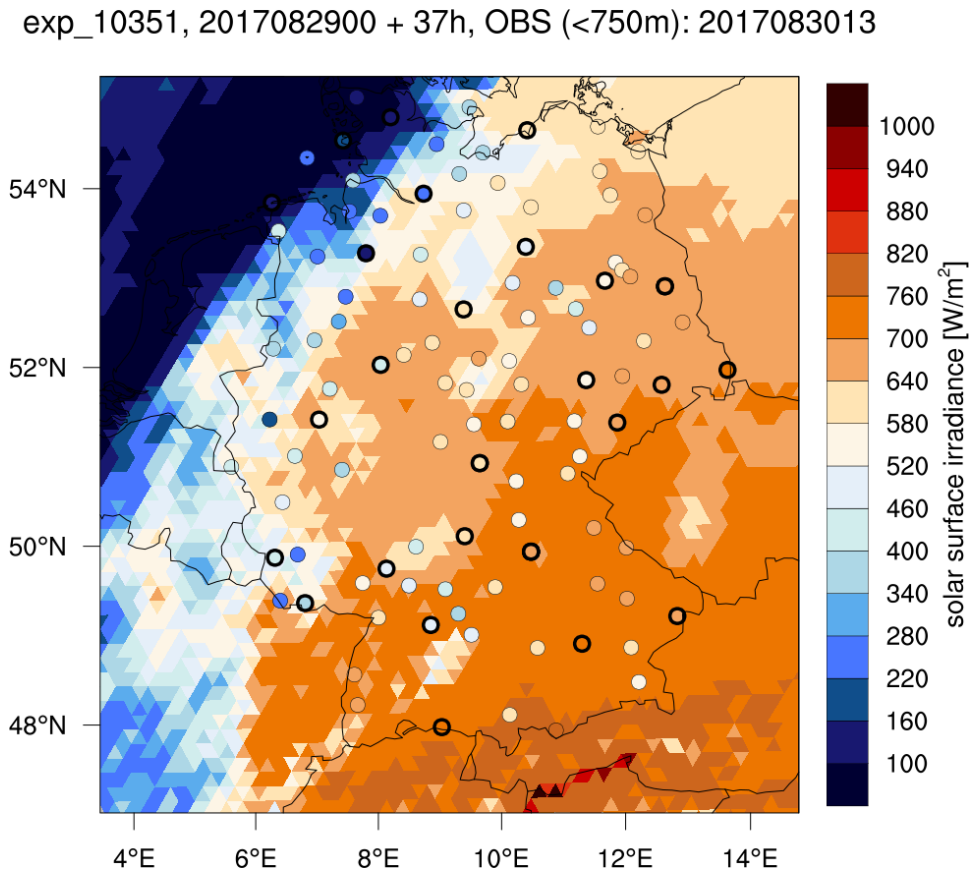
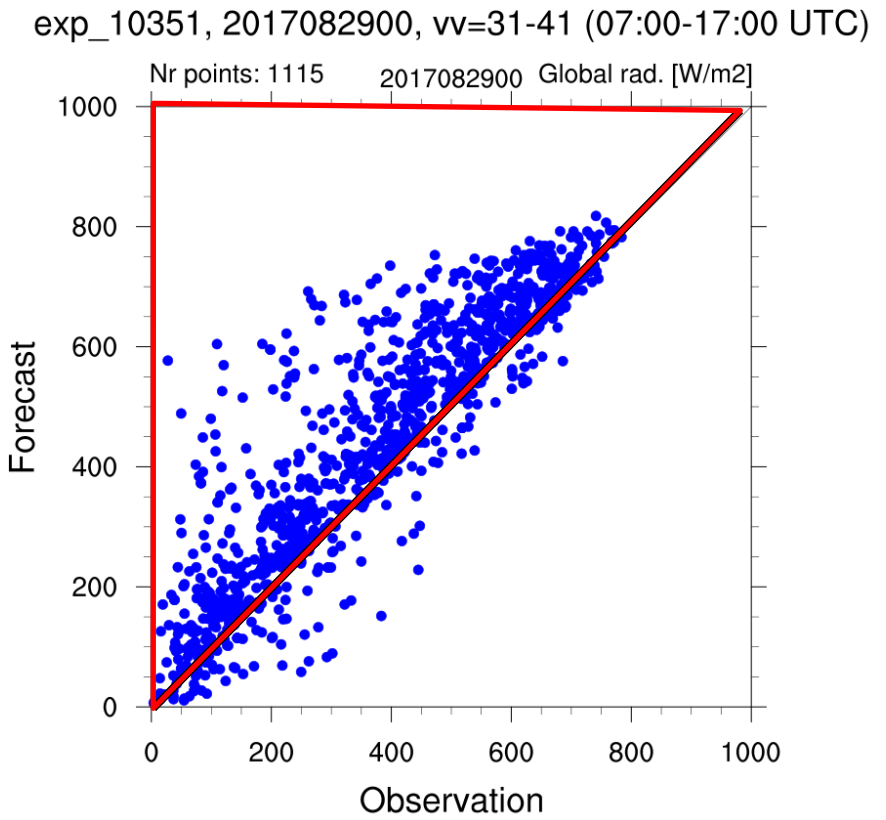
exp_10351





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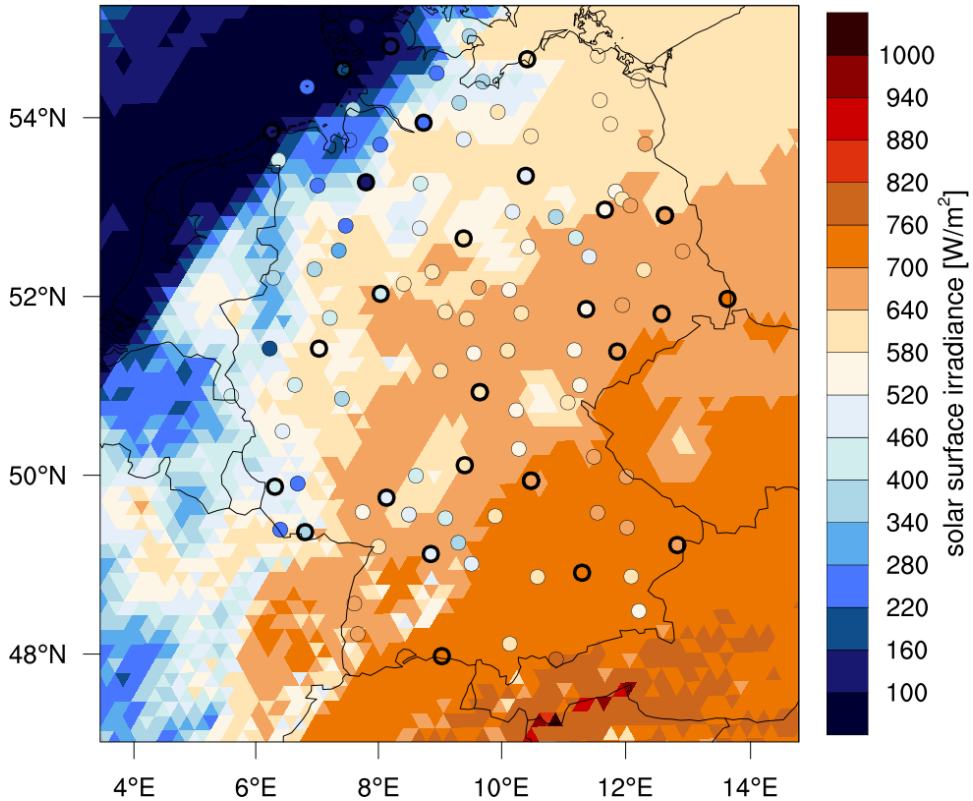
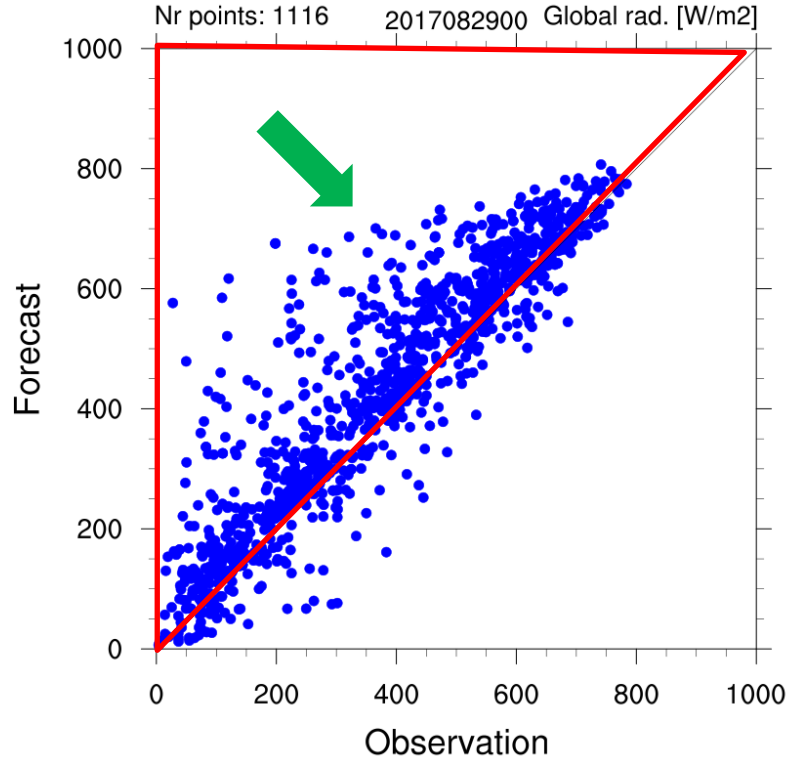
exp_10492

exp_10492, 2017082900 + 37h, OBS (<750m): 2017083013



exp_10492, 2017082900, vv=31-41 (07:00-17:00 UTC)



All: rmse: 105.99, bias: 55.56, mae: 72.56, stdv: 90.31, min: -225.29, max: 548.73

Potential to improve PV-power forecasts during Saharan dust events

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Sensitivity studies concerning dust emission

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Bare soil evaporation scheme

new version

Bare soil evaporation based on a resistance formulation analogue to Ohm´s law (Schulz et al., 2017)

$$E_{bs} = \rho \frac{1}{r_a + r_s}(q_v - q_{sat})$$

ρ : density of air

q_v, q_{sat} : specific humidity of air, saturation specific humidity at surface

r_a, r_s, $r_{s,min}$: aerodynamic resistance, soil resistance, and minimum soil resistance

old version

Bare soil evaporation based on the Biosphere-Atmosphere Transfer Scheme (BATS; Dickinson, 1986)

$$E_{bs} = \rho_w C_k D \frac{s_t}{(z_u z_t)^{\frac{1}{2}}}$$

ρ_w : density of water

s_u : average soil water content in upper z_u = 0.09 m

s_t : average soil water content in upper z_t = 0.81 m

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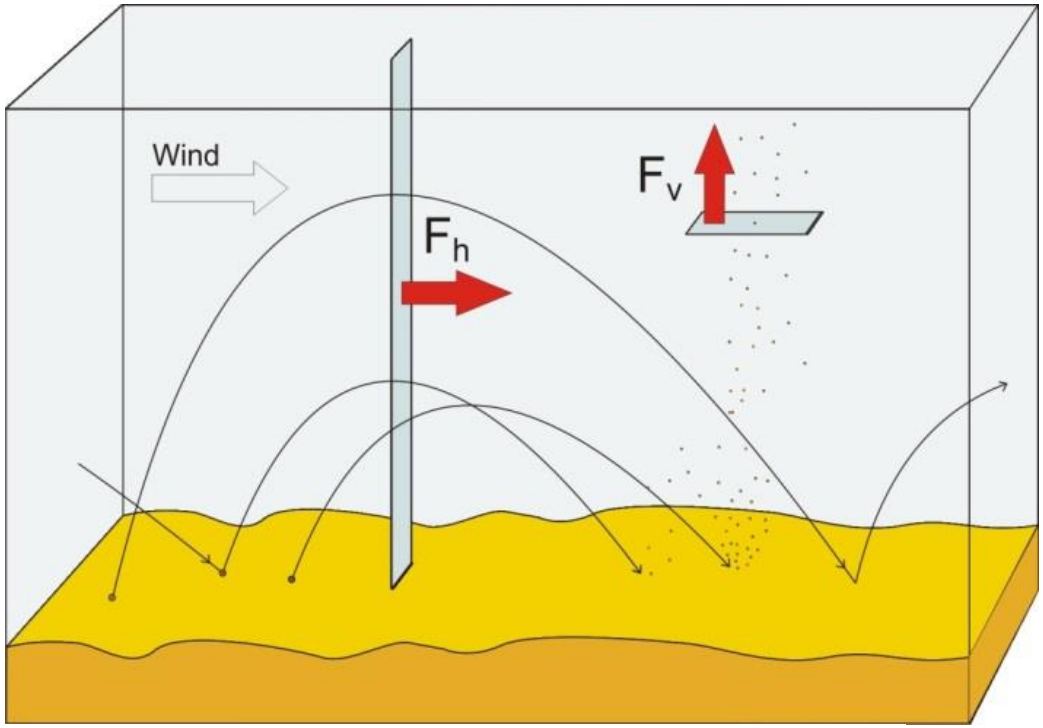
Dust emission



$$u_{*t}(d_{ps}) = f_{z0} \cdot f_\eta \cdot \sqrt{A_n \cdot \left(\frac{\rho_p}{\rho} \cdot g \cdot d_{ps} + \frac{\gamma_n}{\rho \cdot d_{ps}} \right)},$$

soil moisture

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Soil-moisture dependency

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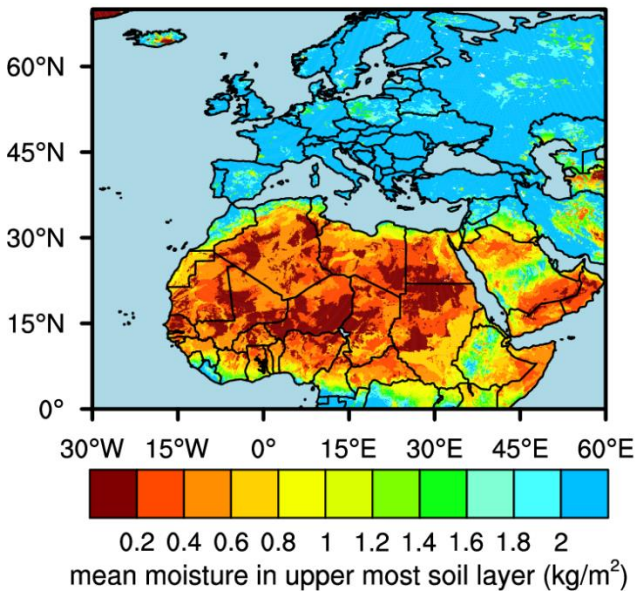
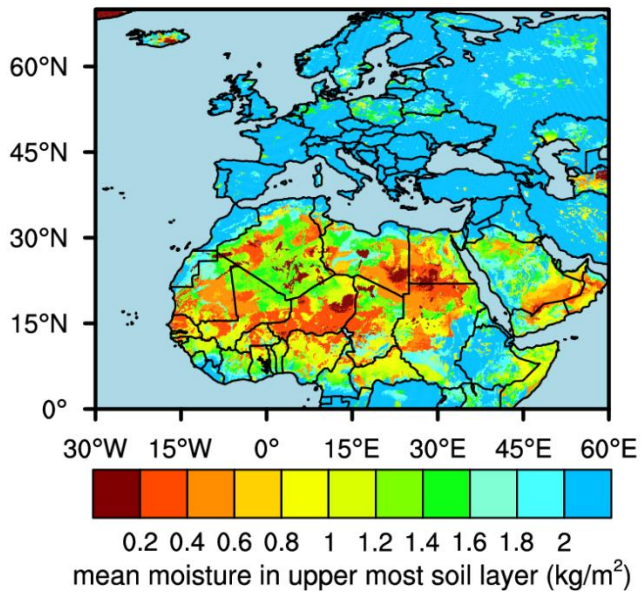
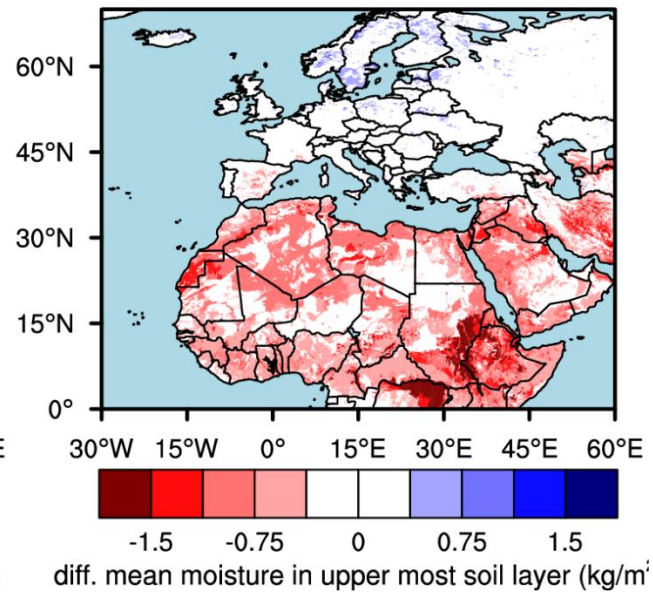
new bare soil evaporation scheme



old version



difference (new - old)



New evaporation scheme: ca. 50% drier soil in Saharan region

10 February 2017 – 15 March 2017

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Soil-moisture dependency

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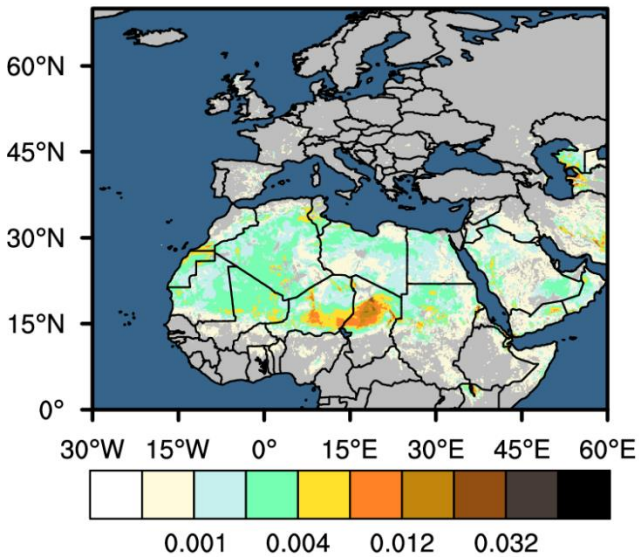
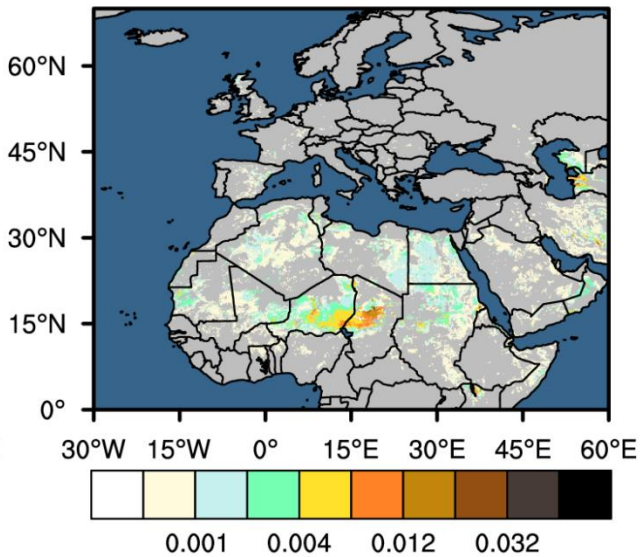
new bare soil evaporation scheme



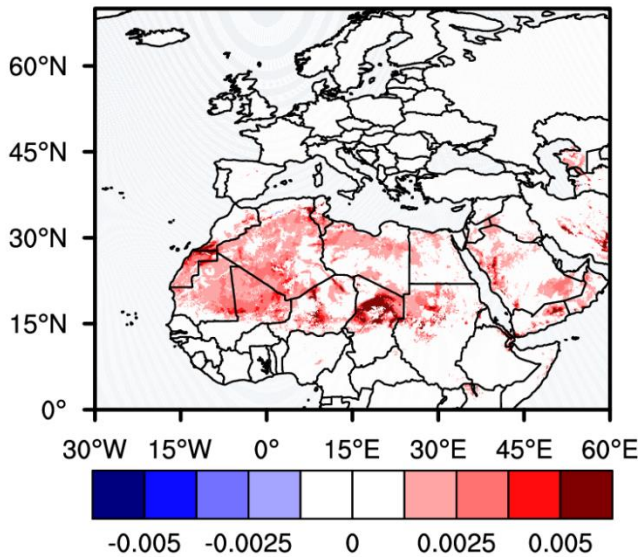
mean acc. emission dust per day (kg/m²)

old version



mean acc. emission dust per day (kg/m²)

difference (new - old)



diff. in mean acc. emission dust (kg/m²)

New evaporation scheme: mean acc. emission dust per day ca. tripled
Better results for the new scheme compared to observations

10 February 2017 – 15 March 2017

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Quasi-operational application

in DWD test bench

NUMEX

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ICON-ART in NUMEX

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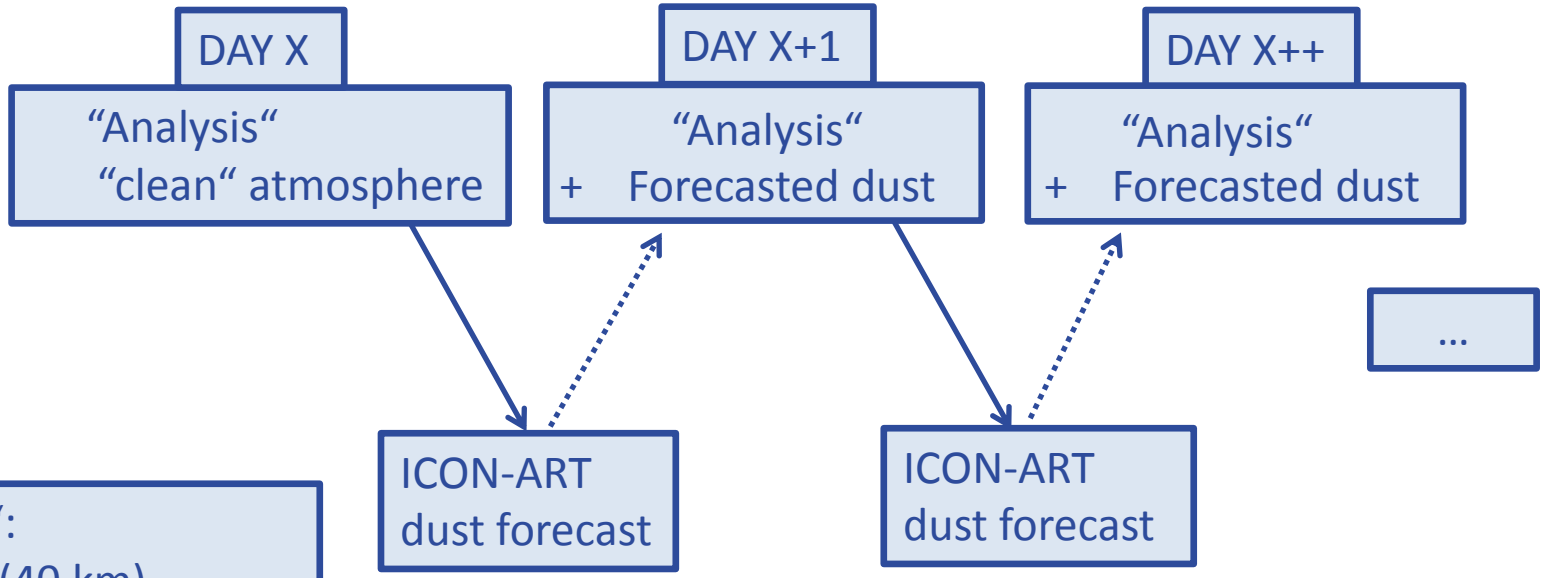

"Analysis":
- r2b06 (40 km)
- One ICON Ensemble Member

? **Aerosol atmosphere interactions?**
→ deterministic Analysis for r2b06 + new r2b07 nest, with dust in the analysis cycle

? **Assimilation of dust?**
→ PhD

Thank you!

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New ICON-ART nest: ICON-EU-(NA)²

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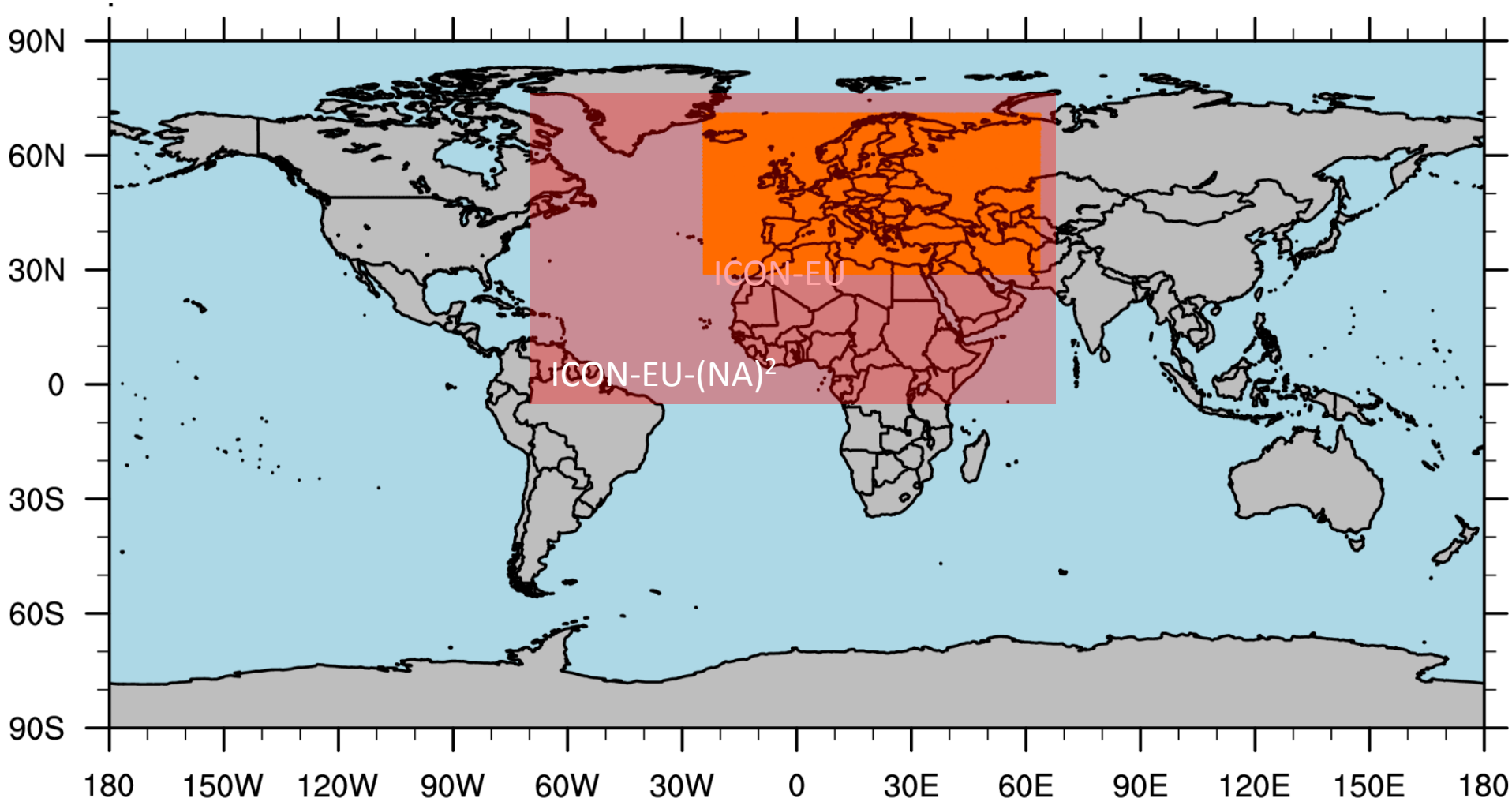

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Literature

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➔ Rieger, D., Bangert, M., Bischoff Gauss, I., Förstner, J., Lundgren, K., Reinert, D., Schröter, J., Vogel, H., Zängl, G., Ruhnke, R., and Vogel, B.: ICON–ART 1.0 – a new online-coupled model system from the global to regional scale, Geosci. Model Dev., 8, 1659–1676,doi:10.5194/gmd-8-1659-2015, 2015.

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