Karlsruher Institut für Technologie | meteo control Energy & Weather Services | Deutscher Wetterdienst – Wetter und Klima aus einer Hand

PerduS: Mineral dust forecasts using ICON-ART

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ICCARUS 2018, Offenbach, Germany

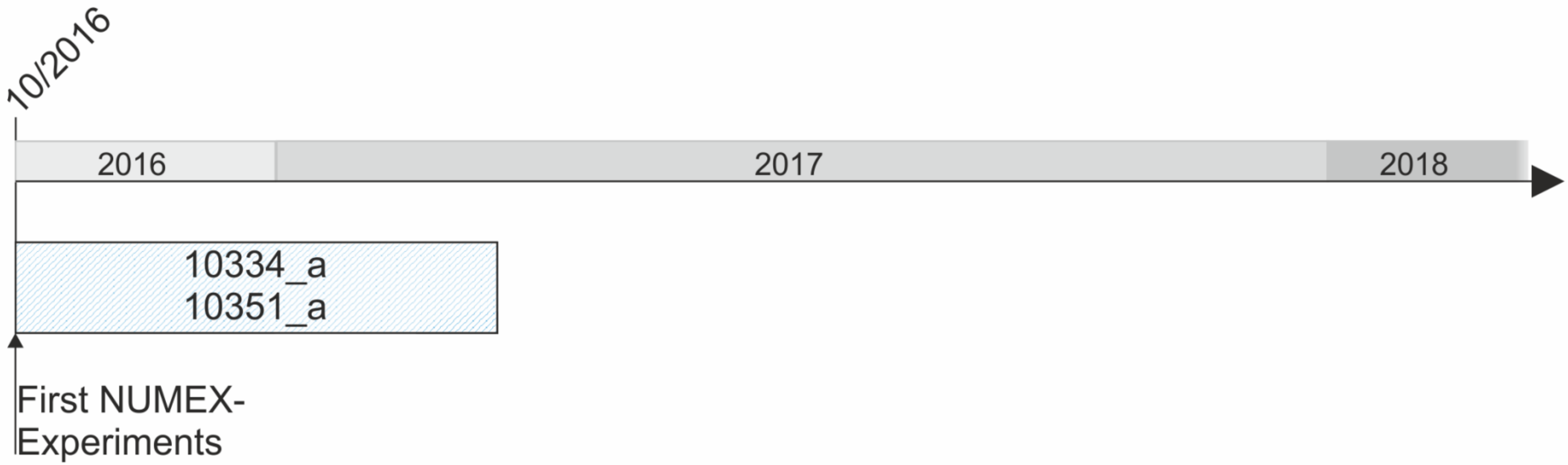
26 February 2017

Outline

- PerduS Milestones

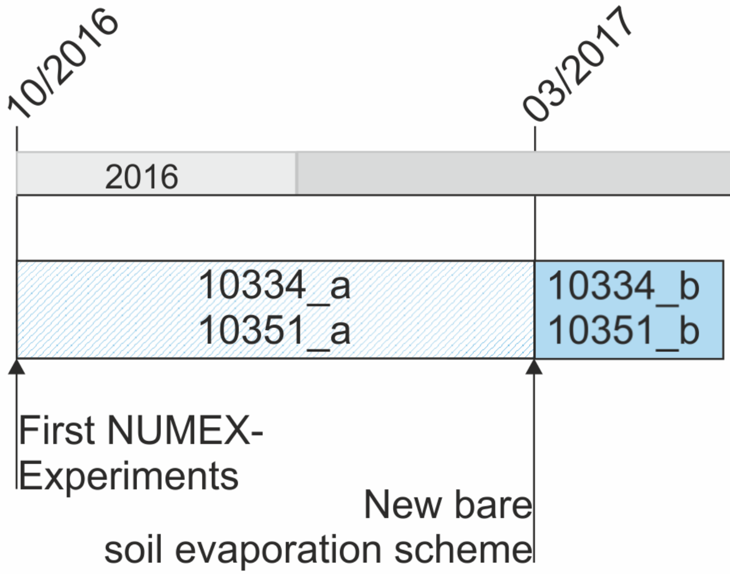
- ICON-ART in EnVar mode
  - First results
- Outlook

PerduS - Milestones



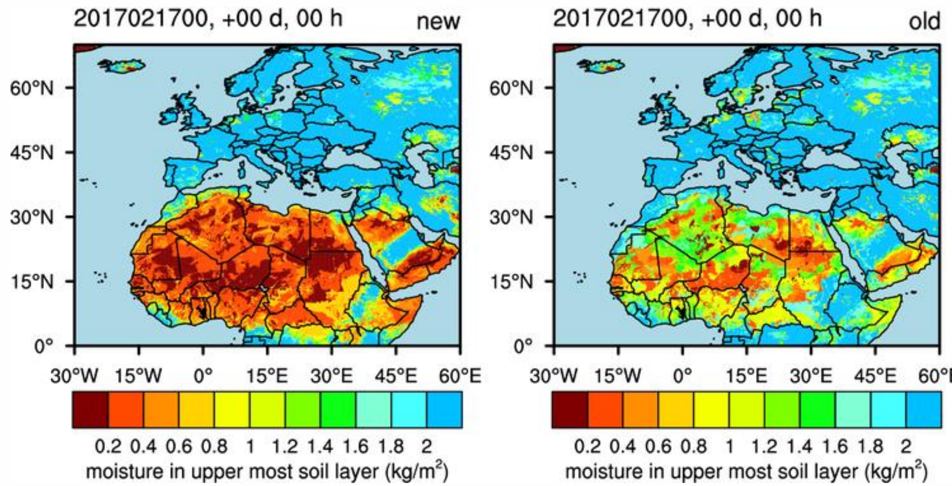
Thanks to
Thomas
Hanisch!

PerduS - Milestones



See presentation by Vanessa Bachmann @ ICCARUS 2017

Bachmann et al. (2017)

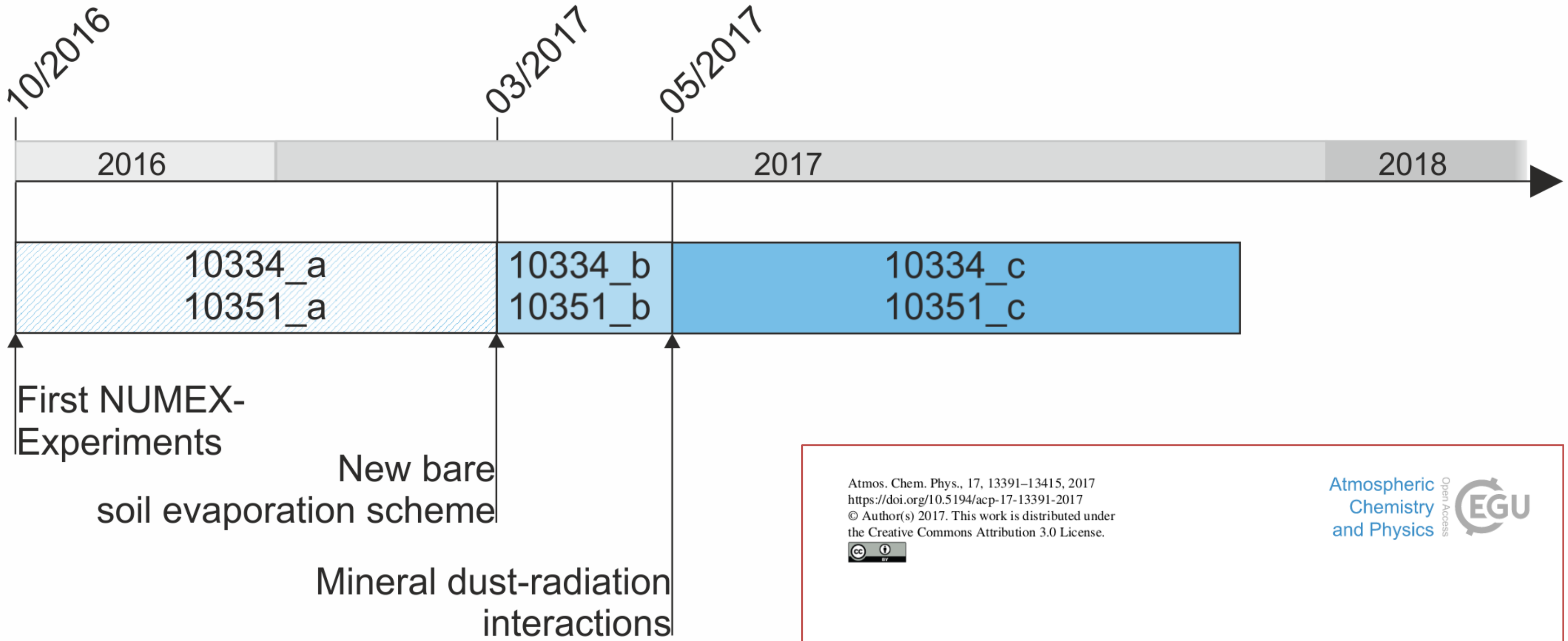


New evaporation scheme: ca. 50% drier soil in Saharan region

-> ~60 % more dust in Saharan region

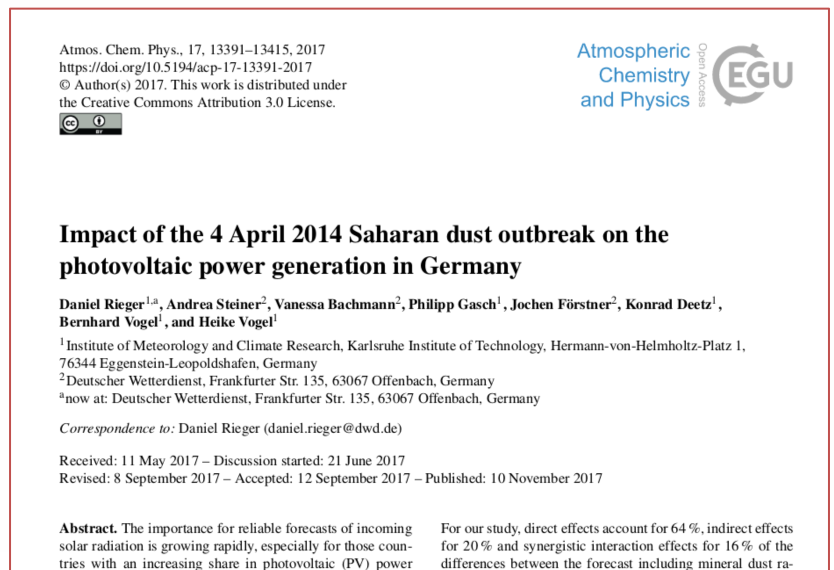
PerduS - Milestones

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



See paper by Daniel Rieger

Rieger et al. (2017)



Atmos. Chem. Phys., 17, 13391–13415, 2017
https://doi.org/10.5194/acp-17-13391-2017

Atmospheric Chemistry and Physics

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

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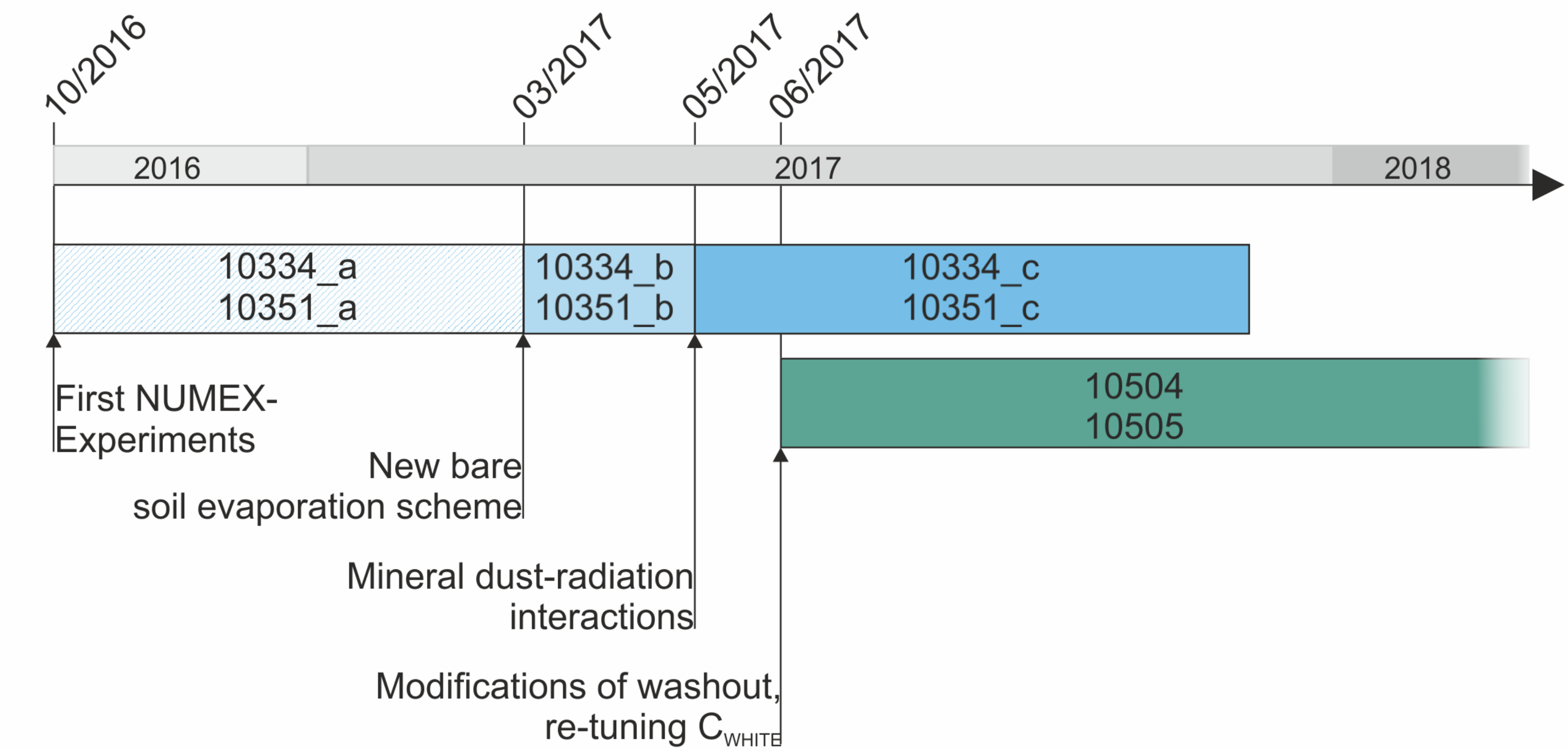
Received: 11 May 2017 – Discussion started: 21 June 2017
Revised: 8 September 2017 – Accepted: 12 September 2017 – Published: 10 November 2017

Abstract. The importance for reliable forecasts of incoming solar radiation is growing rapidly, especially for those countries with an increasing share in photovoltaic (PV) power

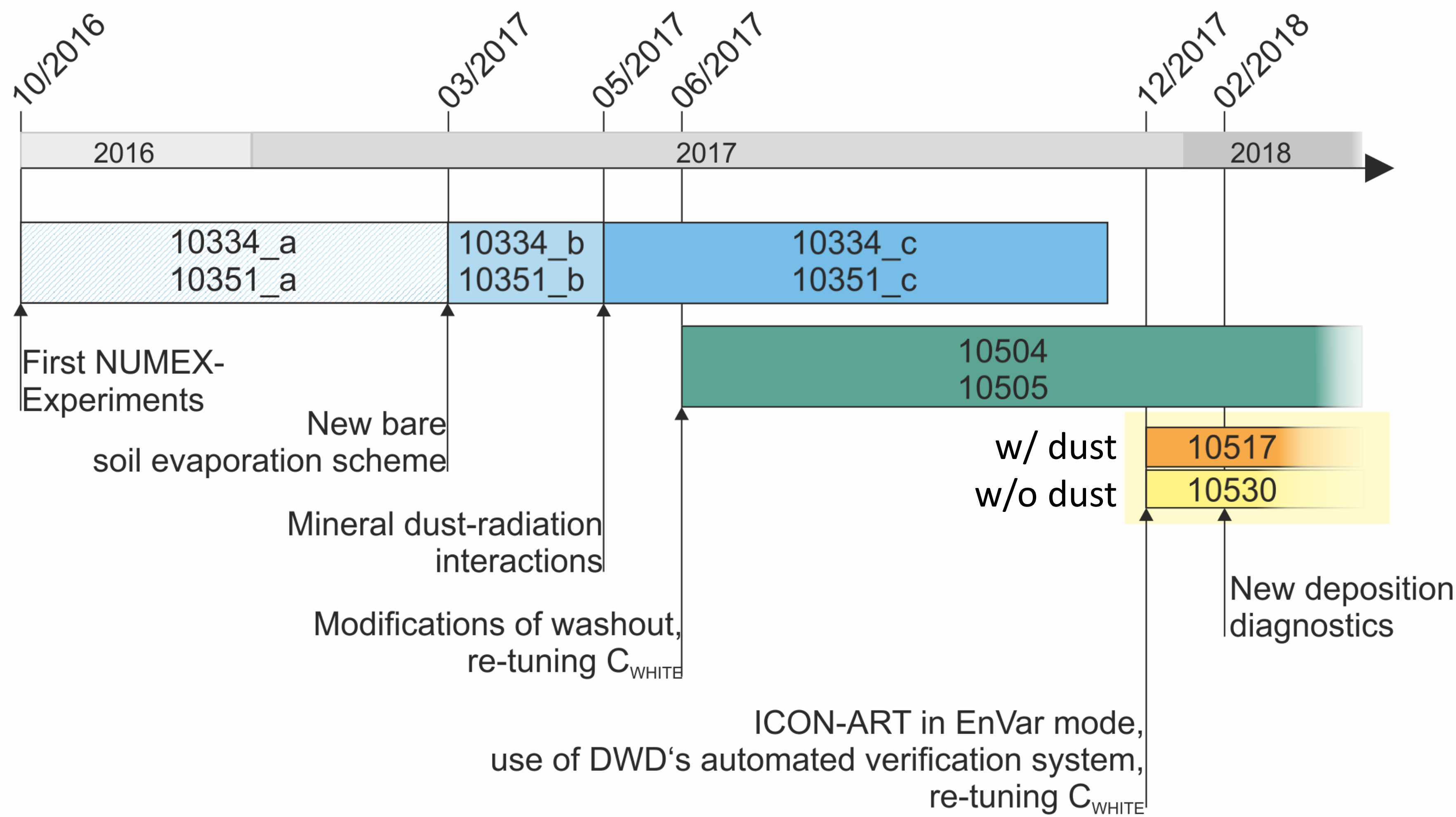
For our study, direct effects account for 64 %, indirect effects for 20 % and synergistic interaction effects for 16 % of the differences between the forecast including mineral dust ra-

PerduS - Milestones



PerduS - Milestones

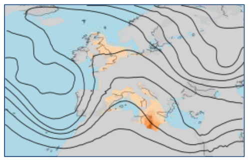
Deutscher Wetterdienst
Wetter und Klima aus einer Hand



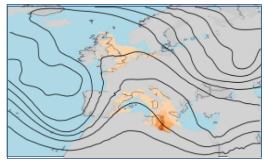
ICON-ART in EnVar mode

ICON-ART assimilation cycle

day X — 3 h ass. cycle — day X + 12 h — day X + 24 h — ...



Analysis (x_a) with Mineral Dust



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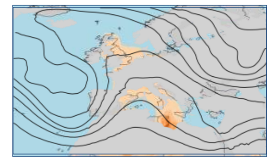
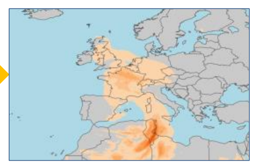


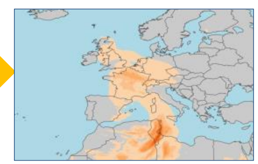
Analysis (x_a) with Mineral Dust

...

ICON-ART forecasts



Coupled Weather- and Mineral Dust Forecast



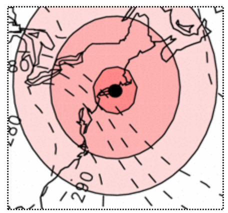
Coupled Weather- and Mineral Dust Forecast

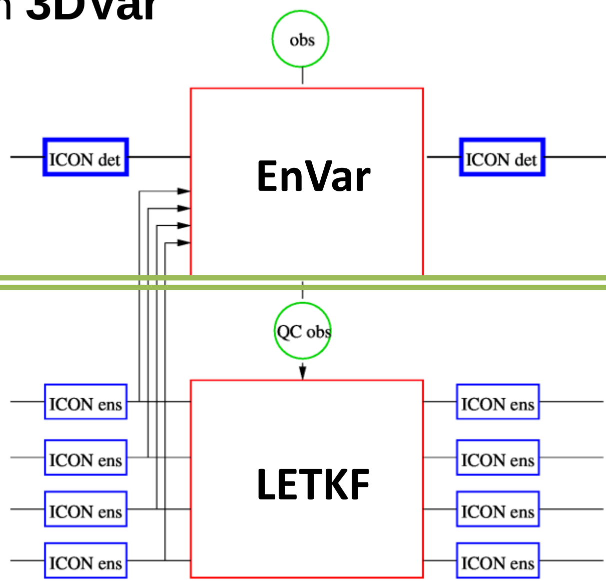
...

Take home message: First guess forecasts (x_b) in assimilation cycle are ICON-ART forecasts with mineral dust, including aerosol radiation interactions

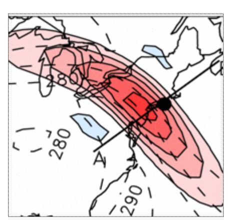
EnVar

Climatological B-matrix "NMC method" based on **3DVar**





flow dependent B-matrix based on **EDA**



3DVar/EnVar:

$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{W}(\mathbf{y}_0 - H(\mathbf{x}_b))$$

$$\mathbf{W} = \mathbf{B}\,\mathbf{H}^T\,(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}$$

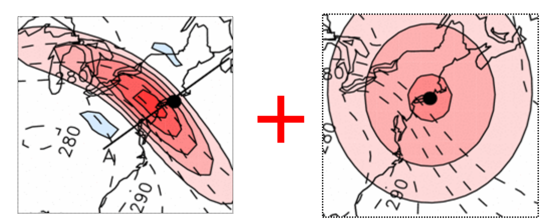
3DVar ⟷ EnVar

ensemble background error covariance matrix in a variational context:

$$\mathbf{B}_{hybrid} = \alpha\,\mathbf{B}_{EnKF} + \beta\,\mathbf{B}_{3DVar}$$

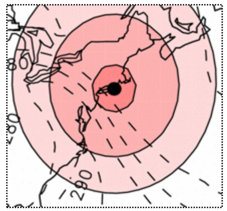
α = 0.7

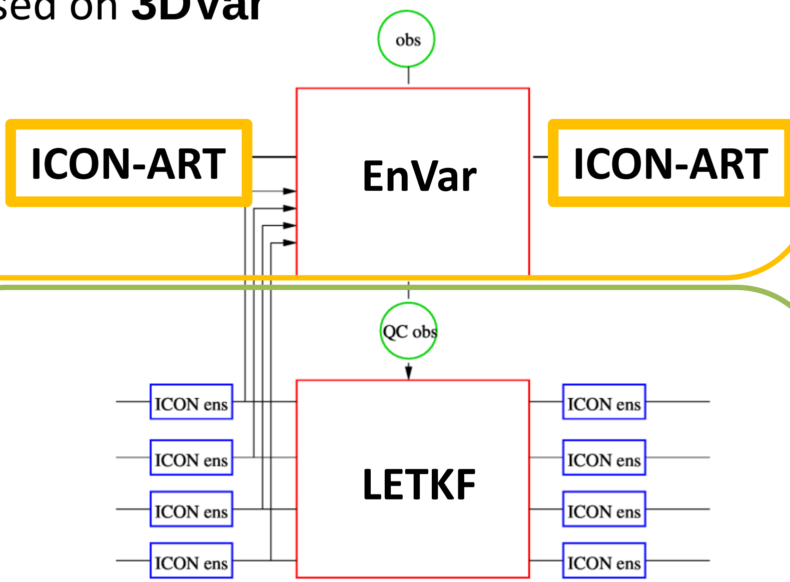
β = 0.3



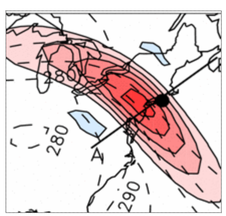
EnVar with dust

Climatological
B-matrix
“NMC method”
based on **3DVar**





flow dependent
B-matrix
based on **EDA**



3DVar/EnVar:

$$\mathbf{x}_a = \mathbf{x}_b + \mathbf{W}(\mathbf{y}_0 - H(\mathbf{x}_b))$$

First guess

$$\mathbf{W} = \mathbf{B}\,\mathbf{H}^T\,(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}$$

3DVar ⟷ EnVar

ensemble background error covariance matrix in a variational context:

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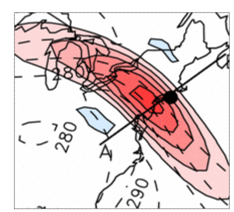
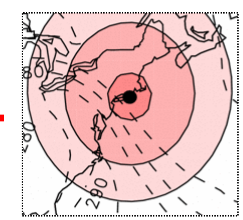
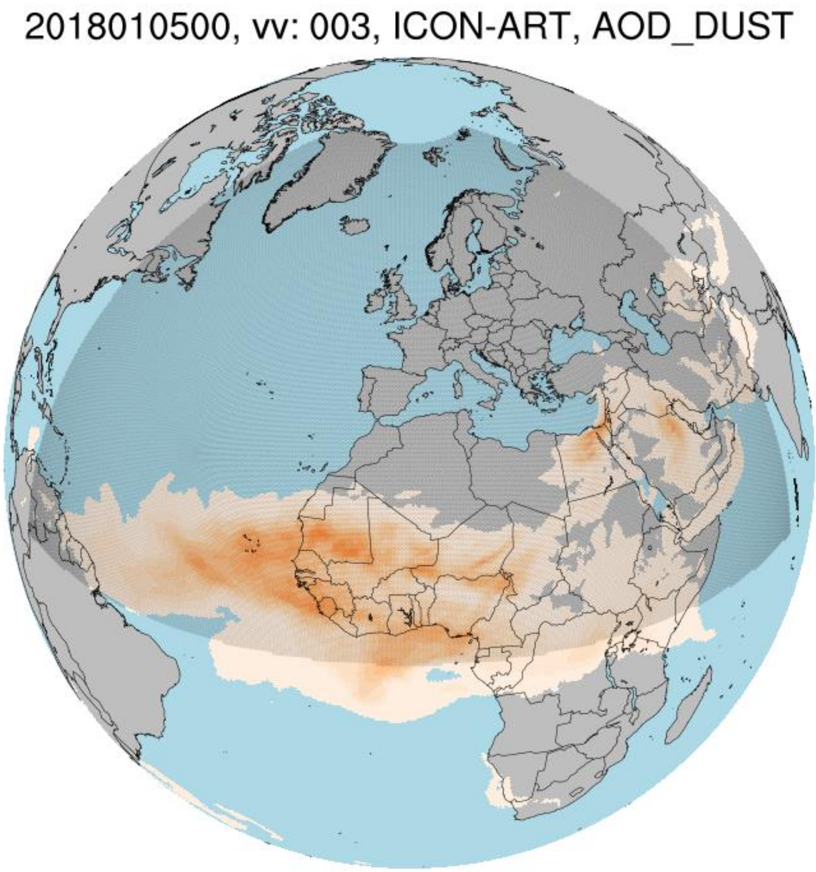
$\beta = 0.3$


+


ICON-ART in EnVar mode

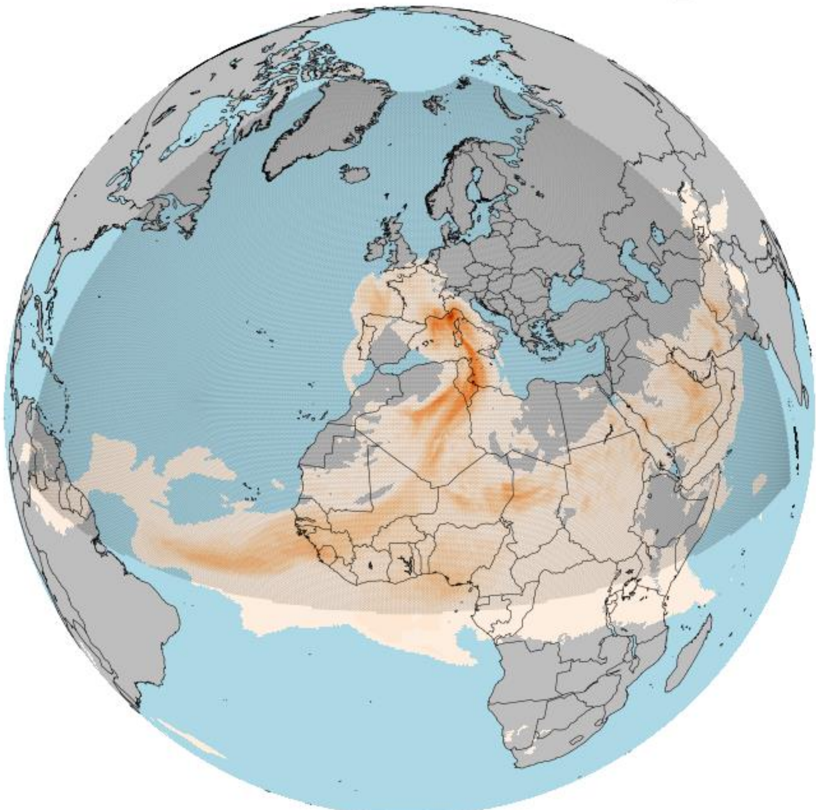


- ➔ Daily 00/12 UTC forecast runs with a lead time up to +180h (Nest: 120h)
- ➔ With / without prognostic dust
- ➔ *How good are the dust forecasts?*
- ➔ How does the forecasted mineral dust compare with the used Tegen climatology*) for mineral dust?
- ➔ How good is the NWP forecast with prognostic dust-radiation interactions?

*) Tegen et al. (1997)

ICON-ART in EnVar mode

2018010800, vv: 012, ICON-ART, AOD_DUST



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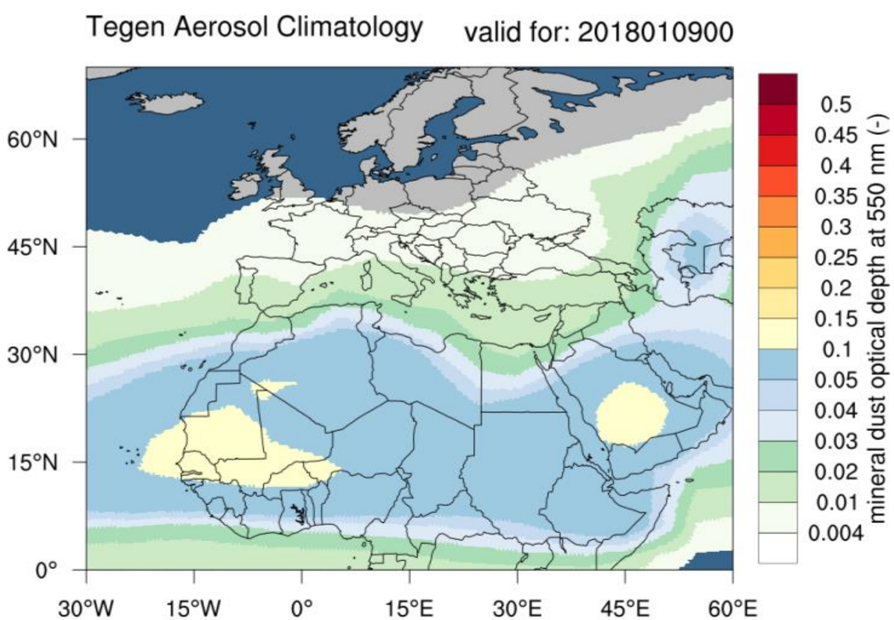
Tegen Aerosol Climatology

➔ Mineral dust optical depth for 09/01/2018:

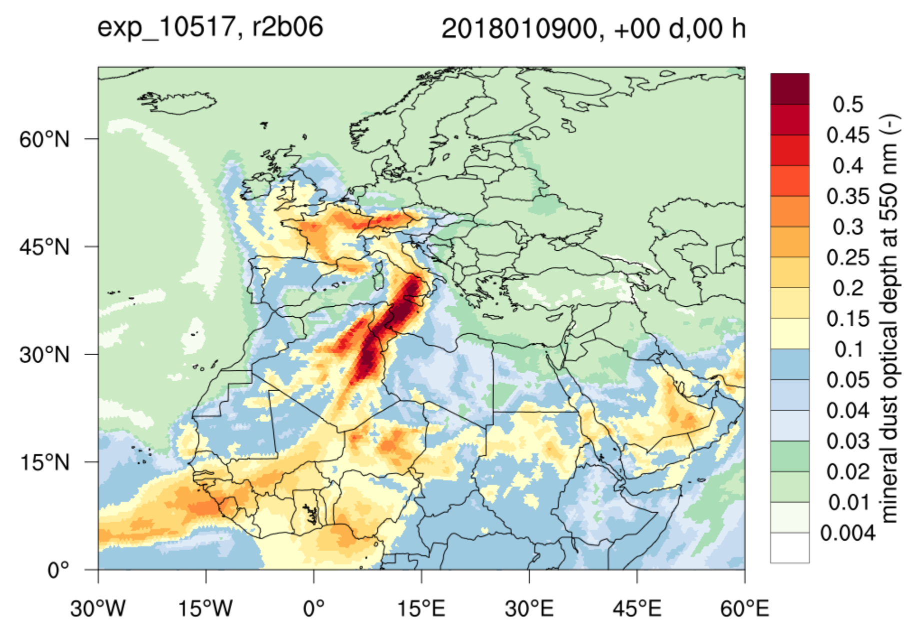
Tegen



mean: 0.04, max: 0.13, std: 0.03 (plot)

mean: 0.01, max: 0.17, std: 0.02 (global)

ICON-ART



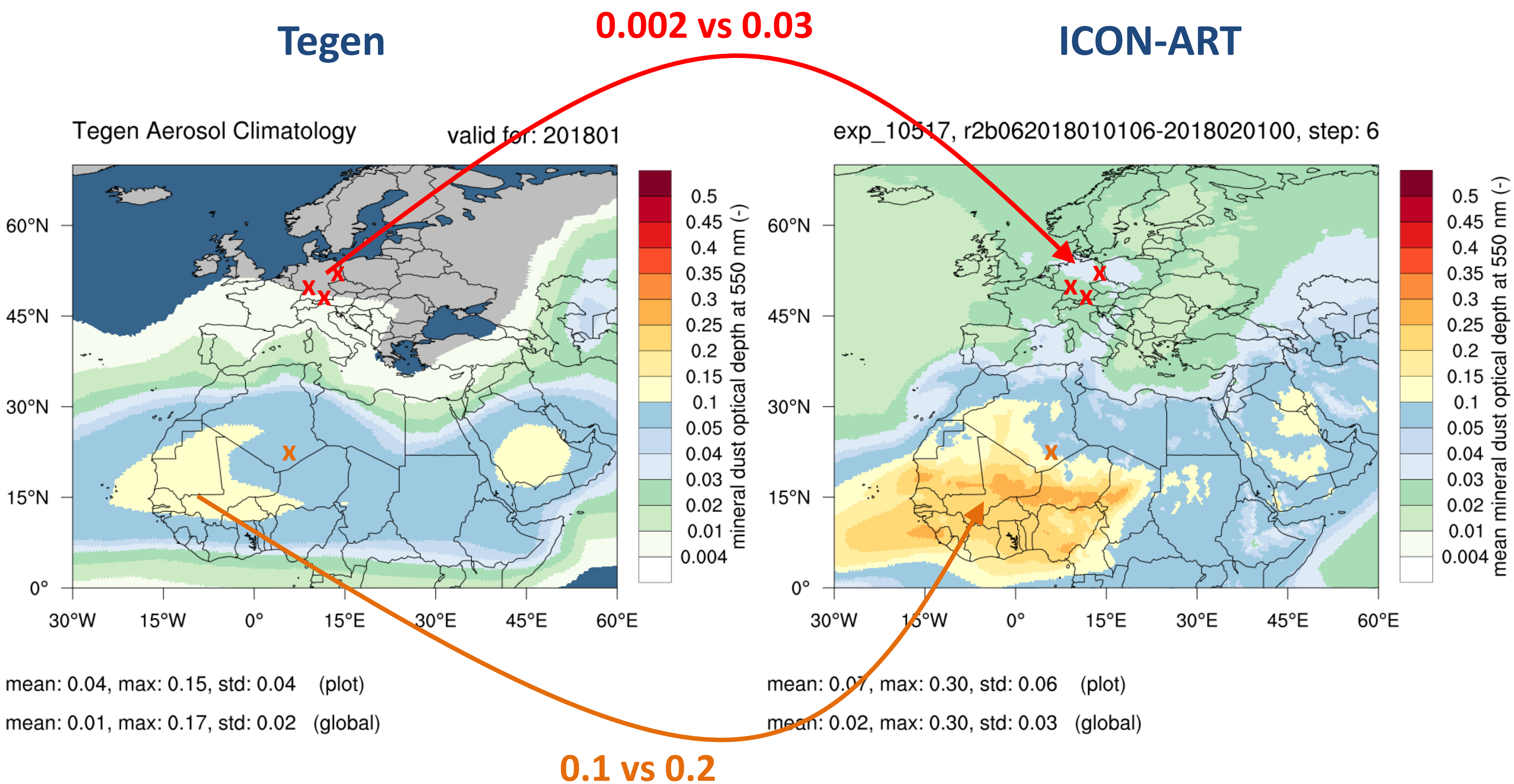
mean: 0.07, max: 0.61, std: 0.08 (plot)

mean: 0.02, max: 0.61, std: 0.04 (global)

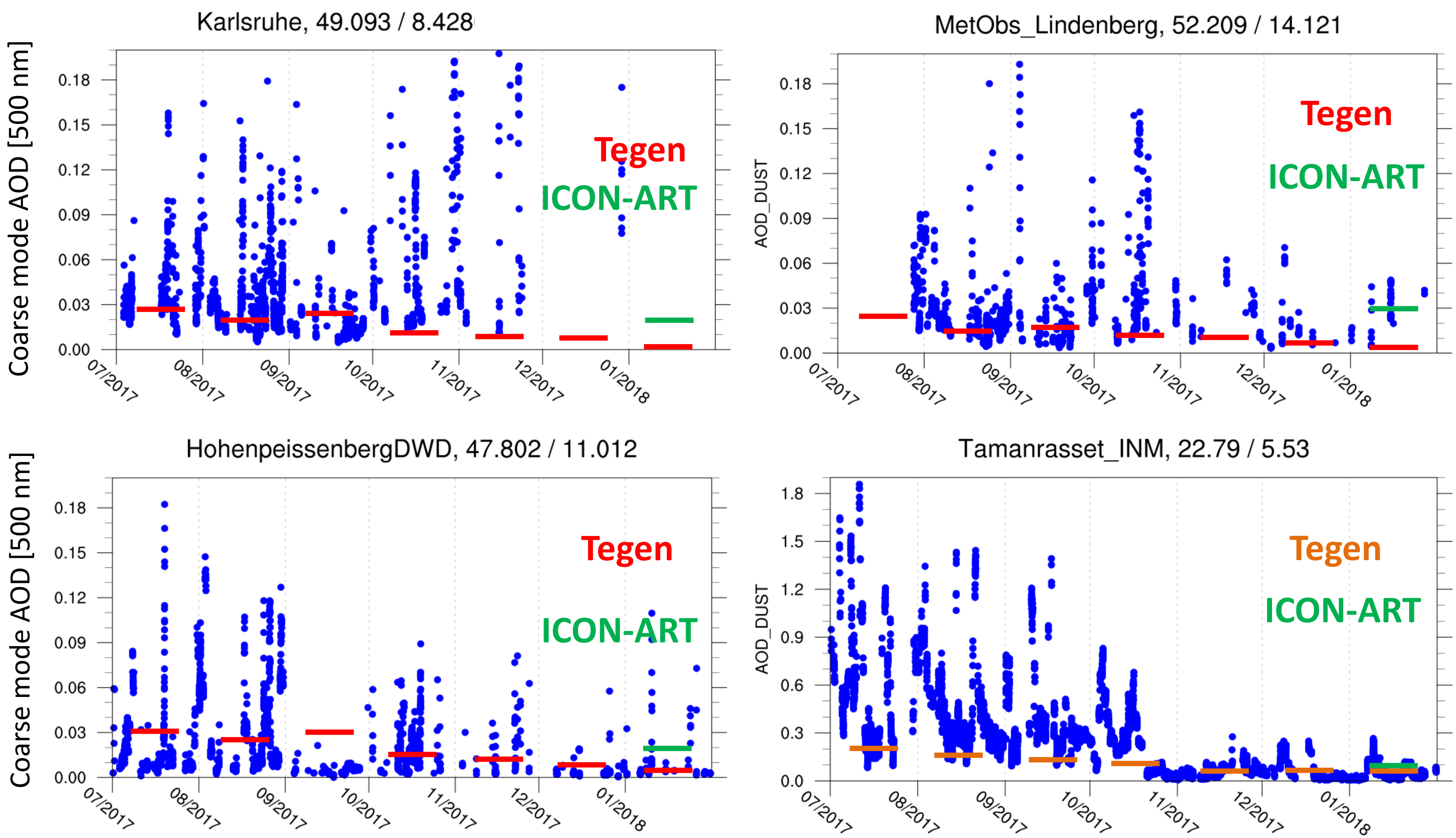
Tegen Aerosol Climatology

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

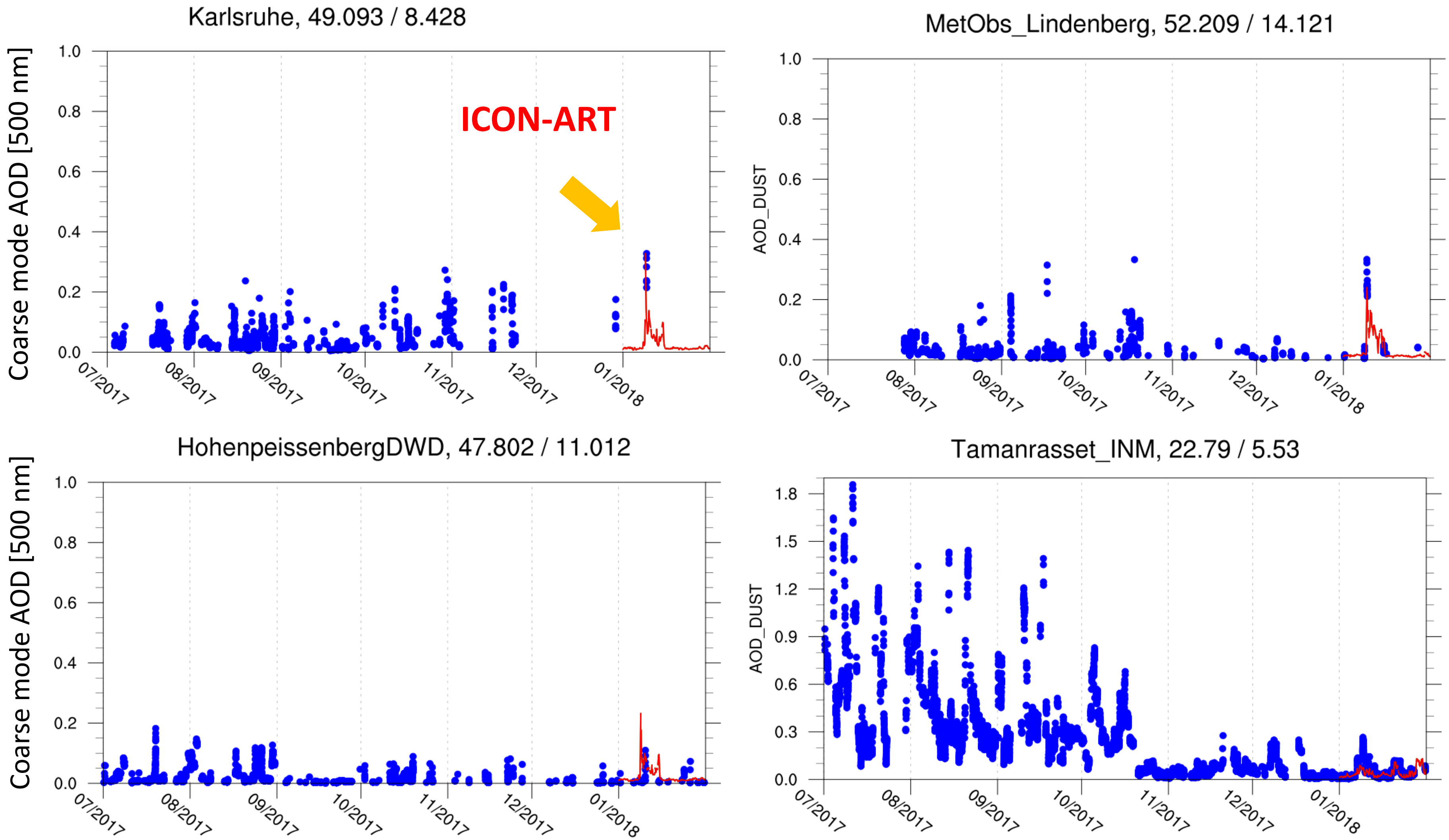
➔ Mineral dust optical depth for 01/2018:



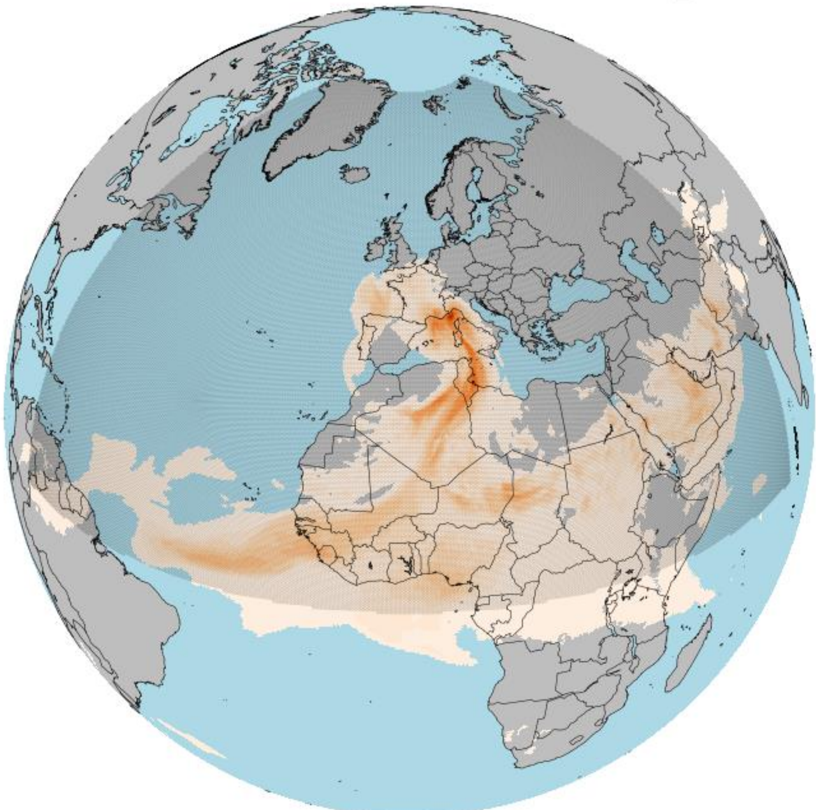
Aeronet Observations



Aeronet Observations



ICON-ART in EnVar mode



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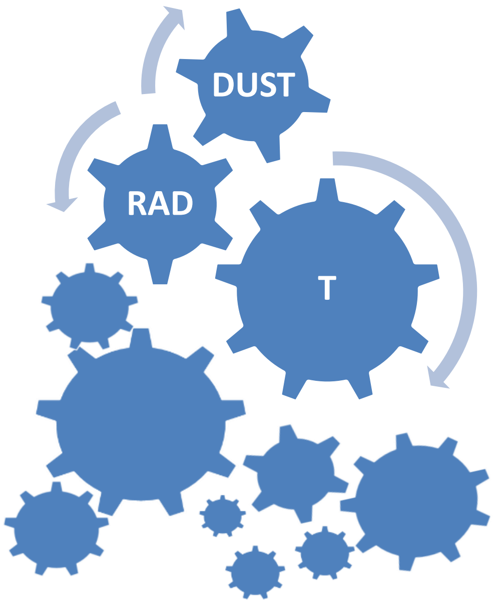
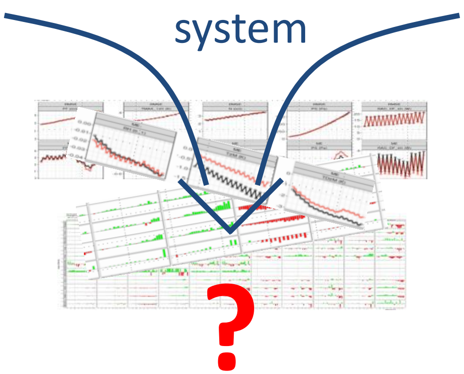
Verification

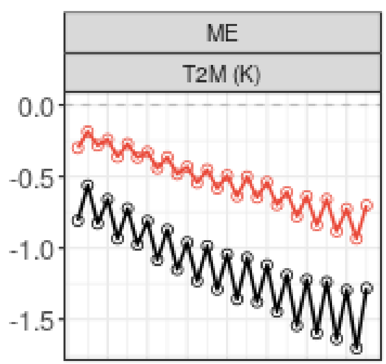


Automated verification system

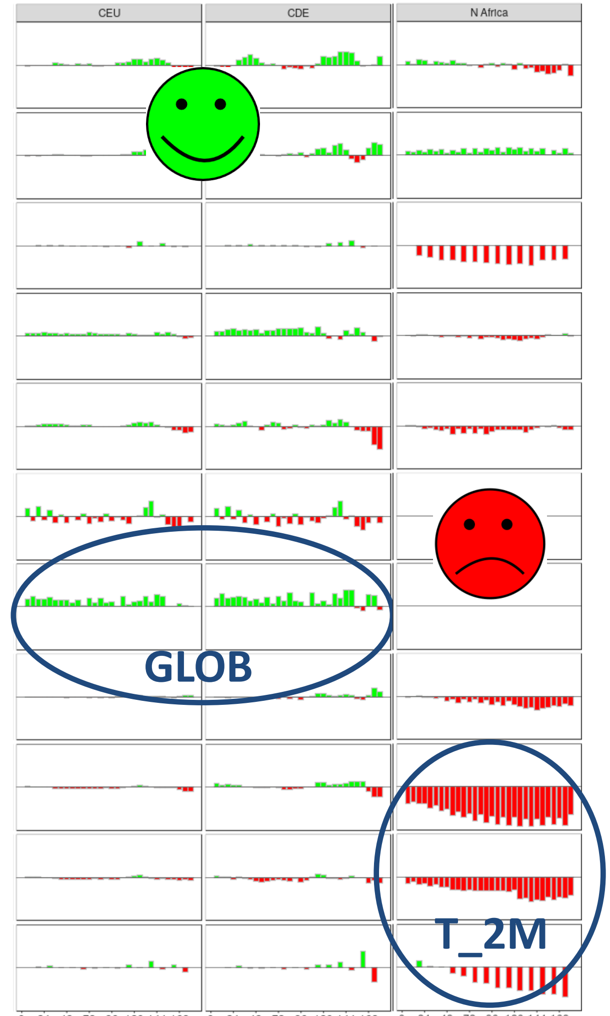


→ Improvement for DE/EU scores

→ **BUT:**
Strong increase of negative Temperature Bias in N-Africa



w/o dust
w/ dust



Verification

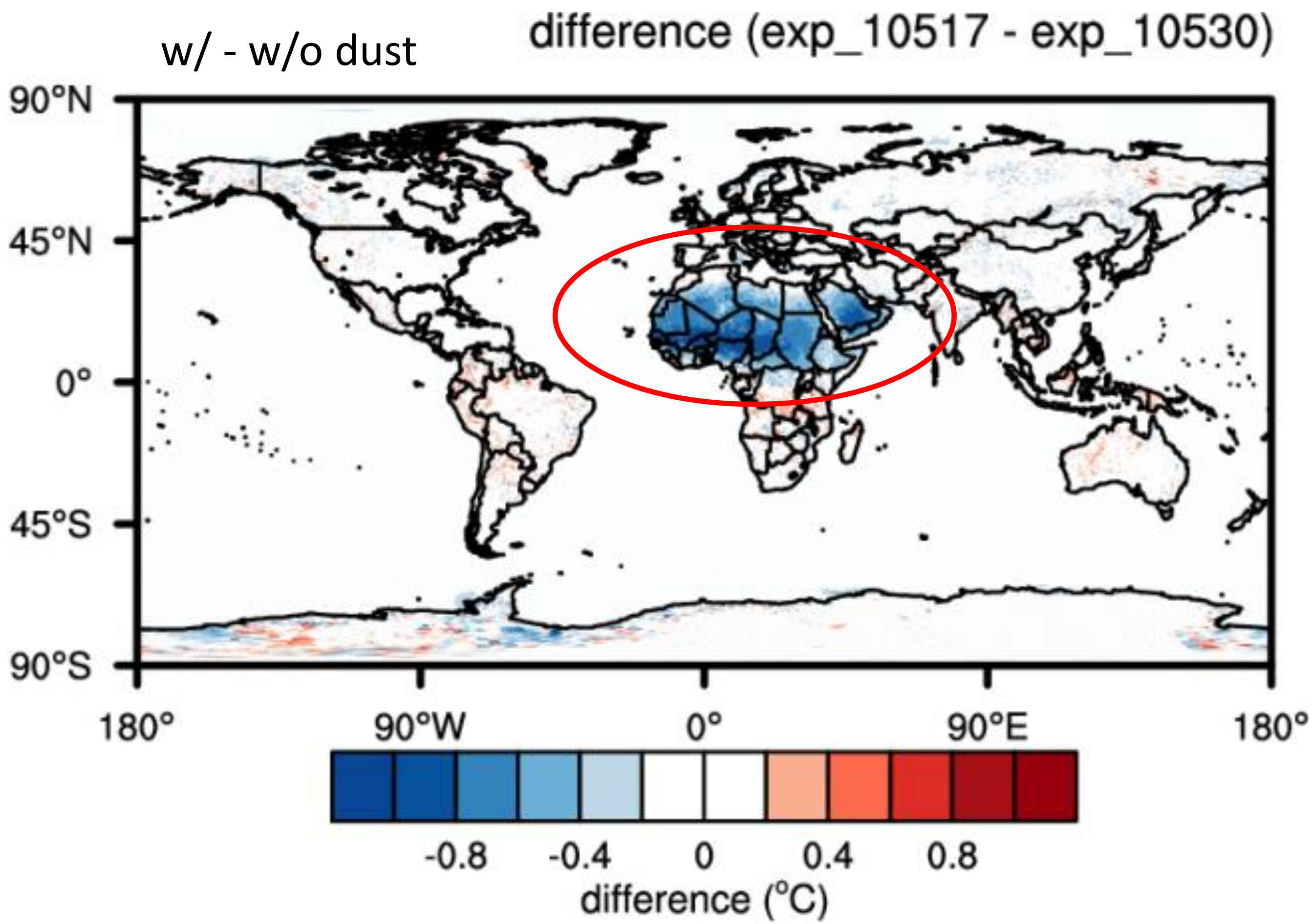
➔ 2m Temperature:

Mean of all 6/12/18/24 h forecasts in 01/2018

w/ - w/o dust

Cooling of N-Africa

- ~ -0.5°C to -0.8°C on monthly average
- Stronger during night than during day



Verification

→ ICON in Sahara-region:

too sunny, too dry, too cold

→ Expectation / Hope:

Longwave radiative heating of increased dust concentration in ICON-ART should reduce the negative Temperature Bias in N-Africa

(as shown by case studies

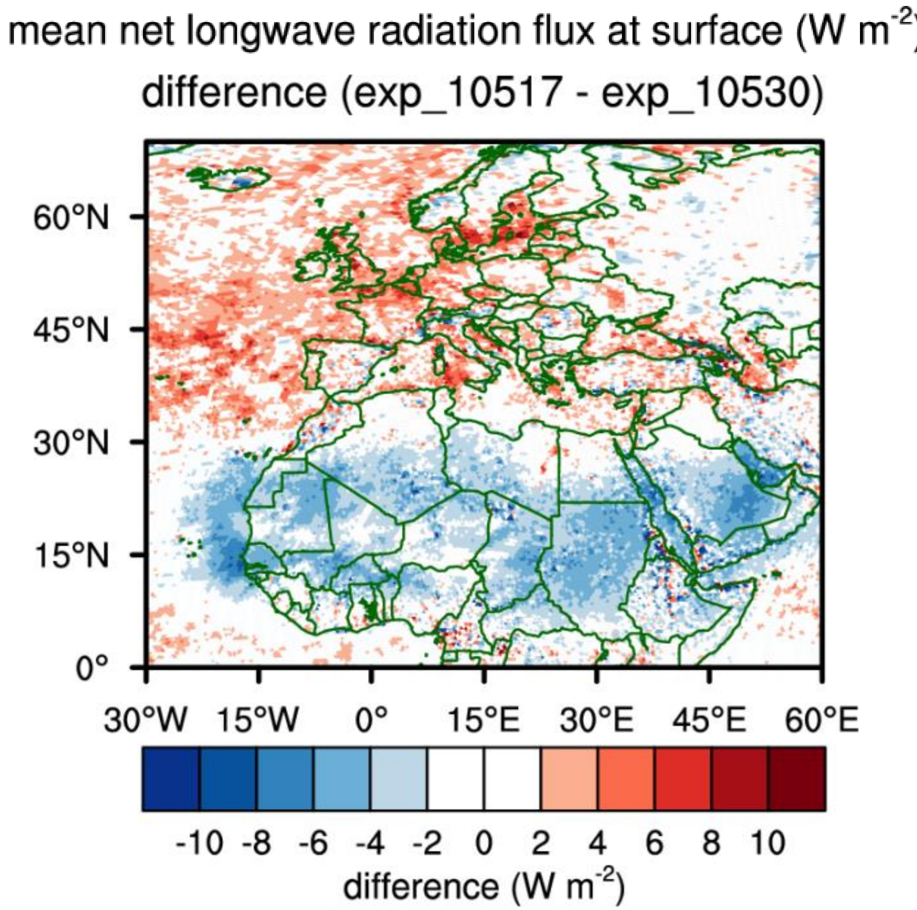
e.g. Gasch et al., 2017)

→ BUT:

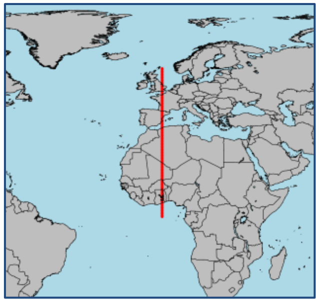
On Average:

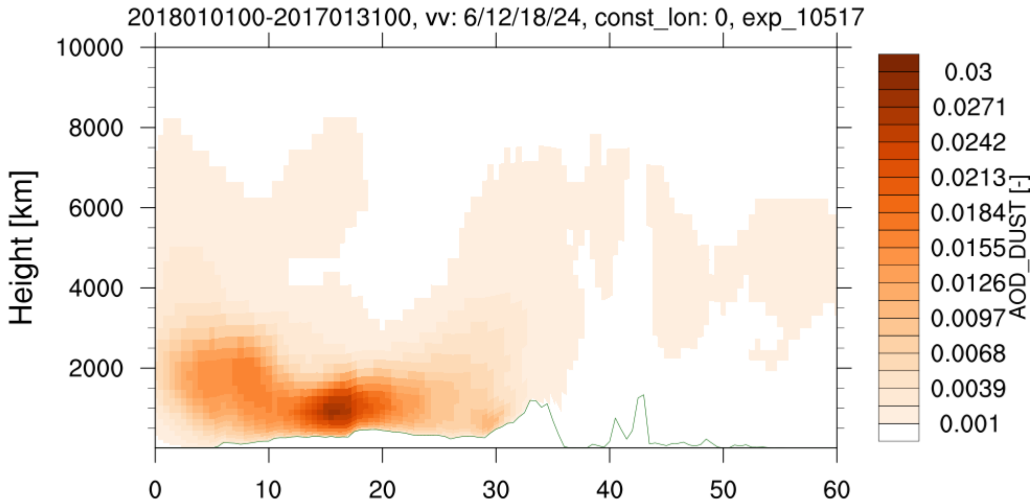
Shortwave radiative effects > longwave radiative effects of increased dust

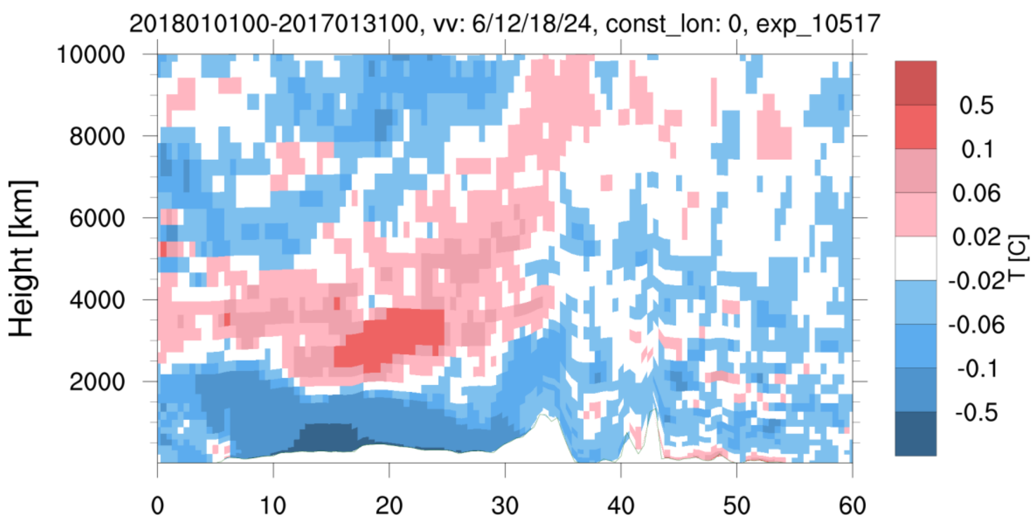
2018/01, 21 UTC – 3UTC



Verification







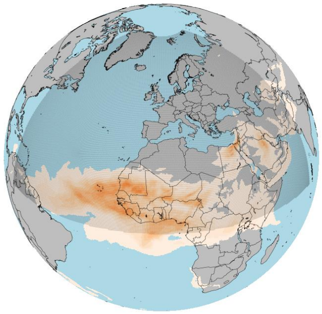
➔ WHY?

- Longwave optical properties of dust?
- Strong stable stratifications?
- How important is the temperature of dust (ICON-ART: $T_{dust} = T_{air}$)?
:

Outlook

- Ongoing improvement of the ICON-ART forecasting system
- Ongoing verification of ICON-ART in EnVar mode
  - Negative Temperature Bias also in other months (with higher dust loads)?
- Assimilation of mineral dust → PhD by Vanessa Bachmann
- Can the prognostic dust be used for the operational NWP?

Thank You!



Literature

➔ Bachmann, V., Steiner, A., Förstner, J., & the PerduS-Team: Forecasting the reduction in photovoltaic power production during Saharan dust outbreaks, *talk at the COSMO-USER Seminar 2017*, Offenbach, Germany, 2017.

➔ Gasch, P., Rieger, D., Walter, C., Khain, P., Levi, Y., Knippertz, P., and Vogel, B.: Revealing the meteorological drivers of the September 2015 severedust event in the Eastern Mediterranean, *Atmospheric Chemistry and Physics,* 17, 13573–13604, doi: https://doi.org/10.5194/acp-17-13573-2017

➔ Rieger, D., Steiner, A., Bachmann, V., Gasch, P., Förstner, J., Deetz, K., Vogel, B., and Vogel, H.: Impact of the 4 April 2014 Saharan dust outbreak on the photovoltaic power generation in Germany, *Atmospheric Chemistry and Physics,* 17, 13391 – 13415, doi:10.5194/acp-17-13391-2017, 2017

➔ Tegen, I., Hollrig, P., Chin, M., Fung, I., Jacob, D., and Penner, J. et al., Contribution of different aerosol species to the global aerosol extinction optical thickness: Estimates from model results*, J. Geophys. Res.,* 1997, 102, 23895–23915