

Daily global aerosol and radiation forecasts including aerosol-radiation-cloud interaction

May 2020 – April 2024

Photovoltaikertragsprognose
zum besseren Management
des Einflusses des
atmosphärischen Aerosols
auf die Stromnetze in
Deutschland und Europa



March 2016 – Feb. 2020



Vanessa Bachmann,

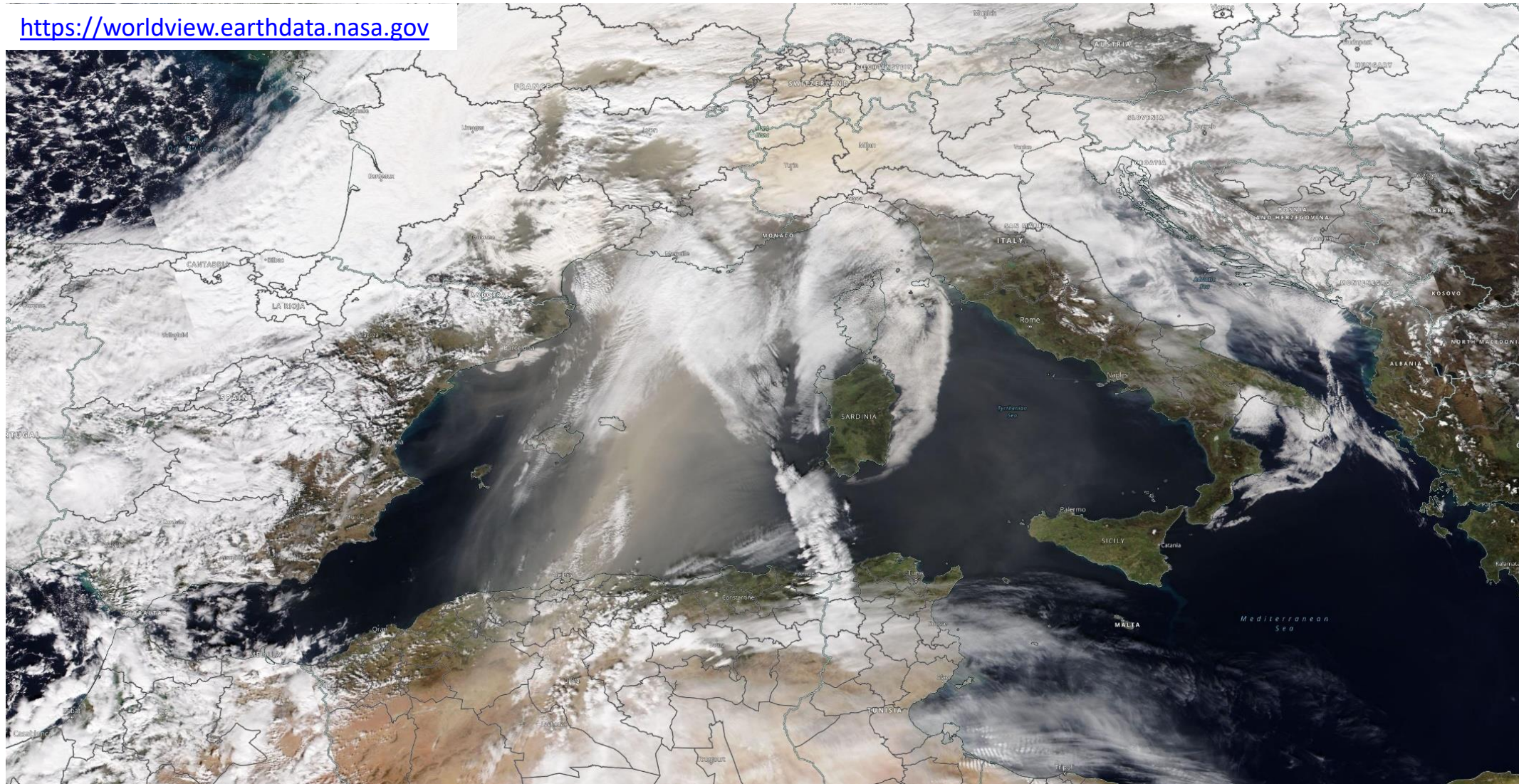
N. Porz, J. Förstner, A. Seifert, F. Filipitsch, L. Doppler, A. Wagner,

I. Mattis, A. Hoshyaripour, H. Vogel, B. Vogel, J. Menken

ICEM
June 2023



<https://worldview.earthdata.nasa.gov>



slide by
Nikolas Porz



QUASI-OPERATIONAL MINERAL DUST FORECASTS WITH ICON-ART AT DWD

Jochen Förstner, Thomas Hanisch and Vanessa Bachmann

ICON-ART running in "EnVar" mode



26 km (13 km)
GLOBAL

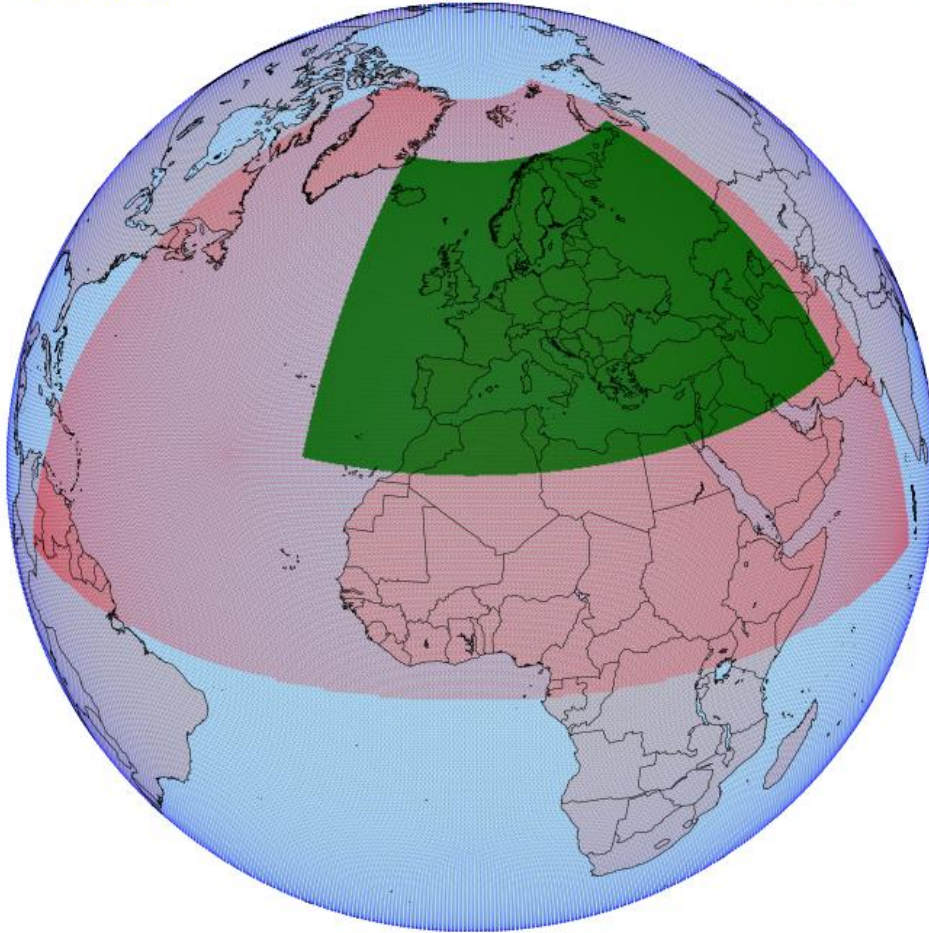
13 km
NEST

(6.5 km)
ICON-EU

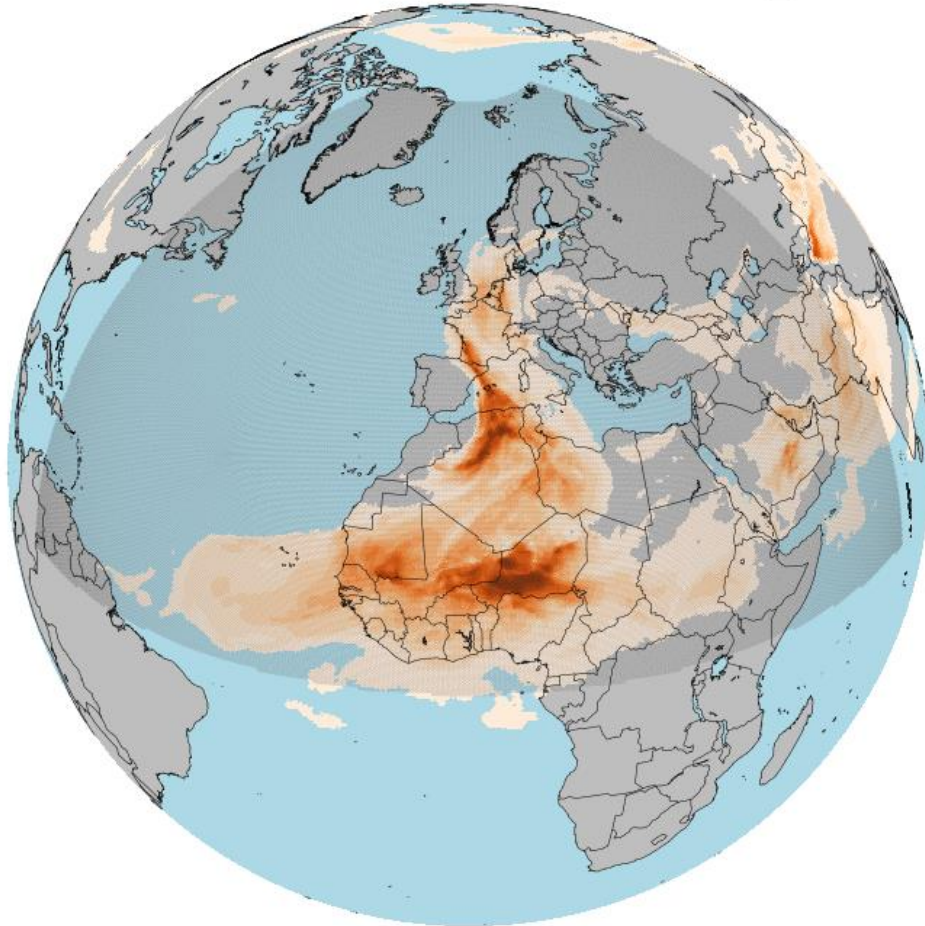
→ spatial resolution:

26 km (global)

13 km (nest, ICON-EU-NA-NA)



2018040800, vv: 003, ICON-ART, AOD_DUST



→ spatial resolution: 26 km (global)
13 km (nest, ICON-EU-NA-NA)

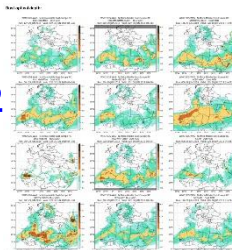
→ since December 2017:

Daily 00 and 12 UTC forecasts up to
+180 h (global), +120 h (nest)

→ two long running experiments in “EnVar” mode:

- with prognostic mineral dust
(quasi-operational mineral dust forecasts)
- with Tegen et al. (1997) dust climatology
(control experiment, similar to operational ICON)

→ data delivery to meteocontrol, KIT, [WMO-SDS-WAS](#)
(Sand and Dust Storm Warning Advisory and Assessment System)



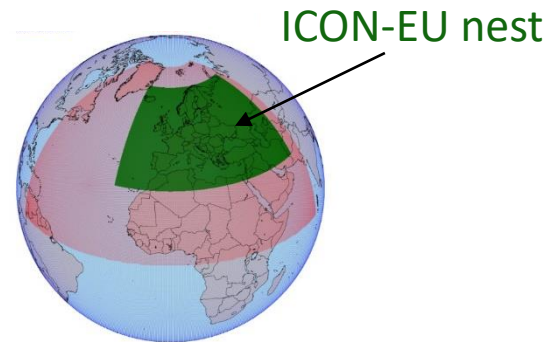
PLANNED OPERATIONAL SETUP FOR ICON-ART AT DWD

EnVar:

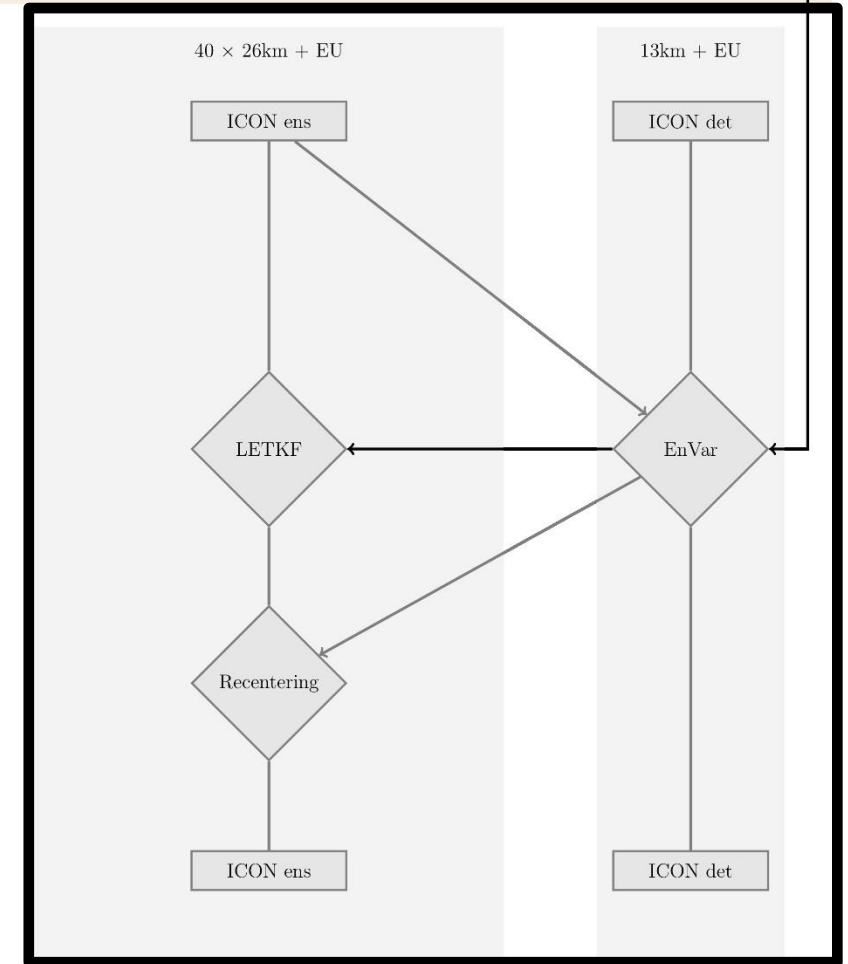
- Initial data for forecasts
- Observation quality control for LETKF

LETKF:

- Dynamical information for deterministic data assimilation
- Initial data for ensemble forecast



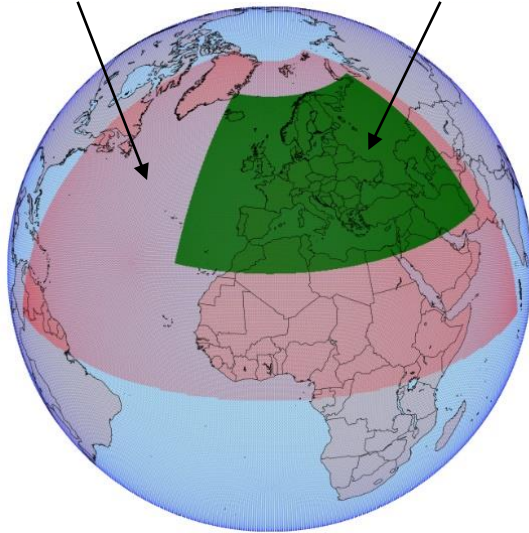
OBSERVATIONS



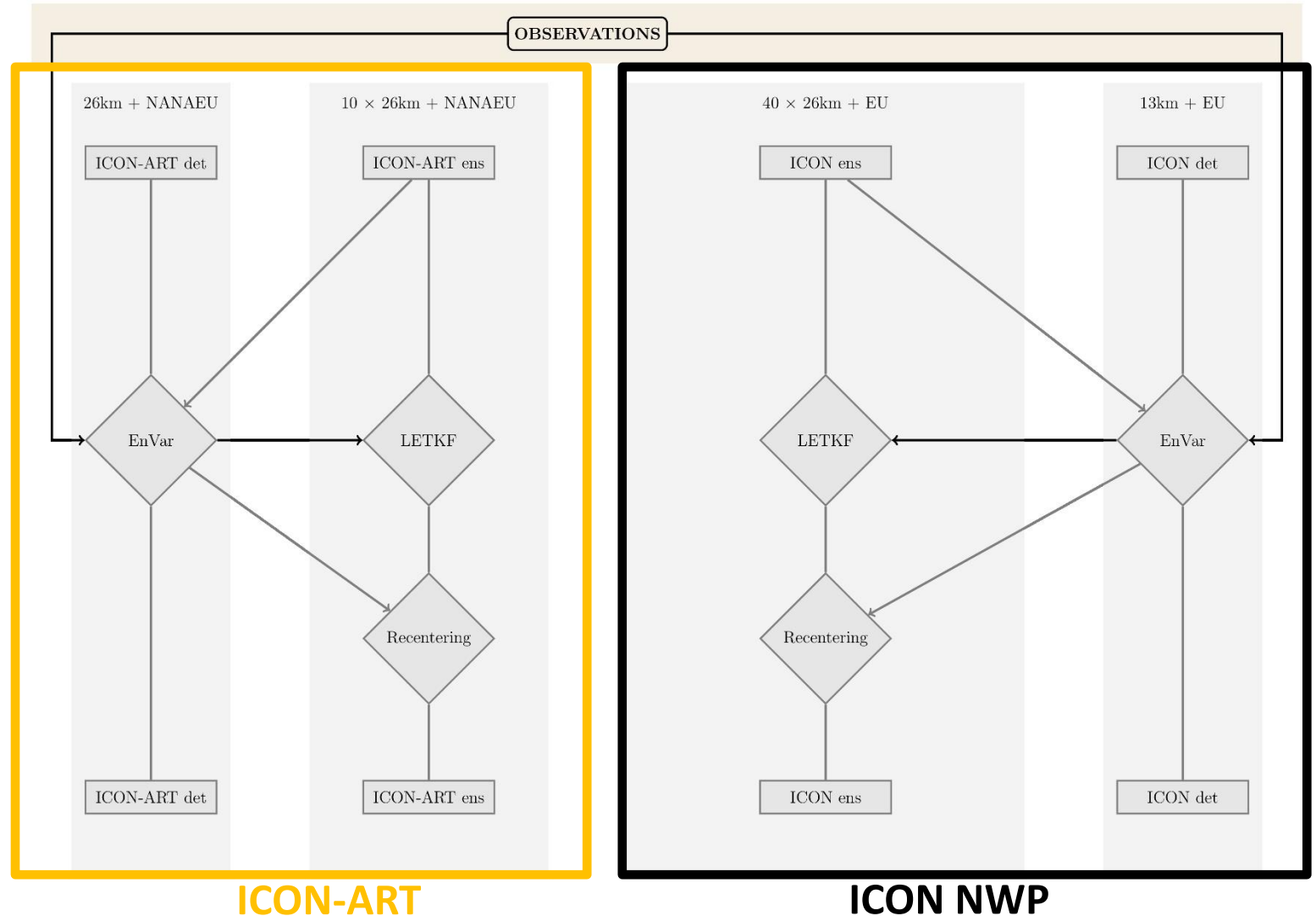
ICON NWP

EnVar and LETKF DA - two systems

ICON-EU-NA-NA ICON-EU

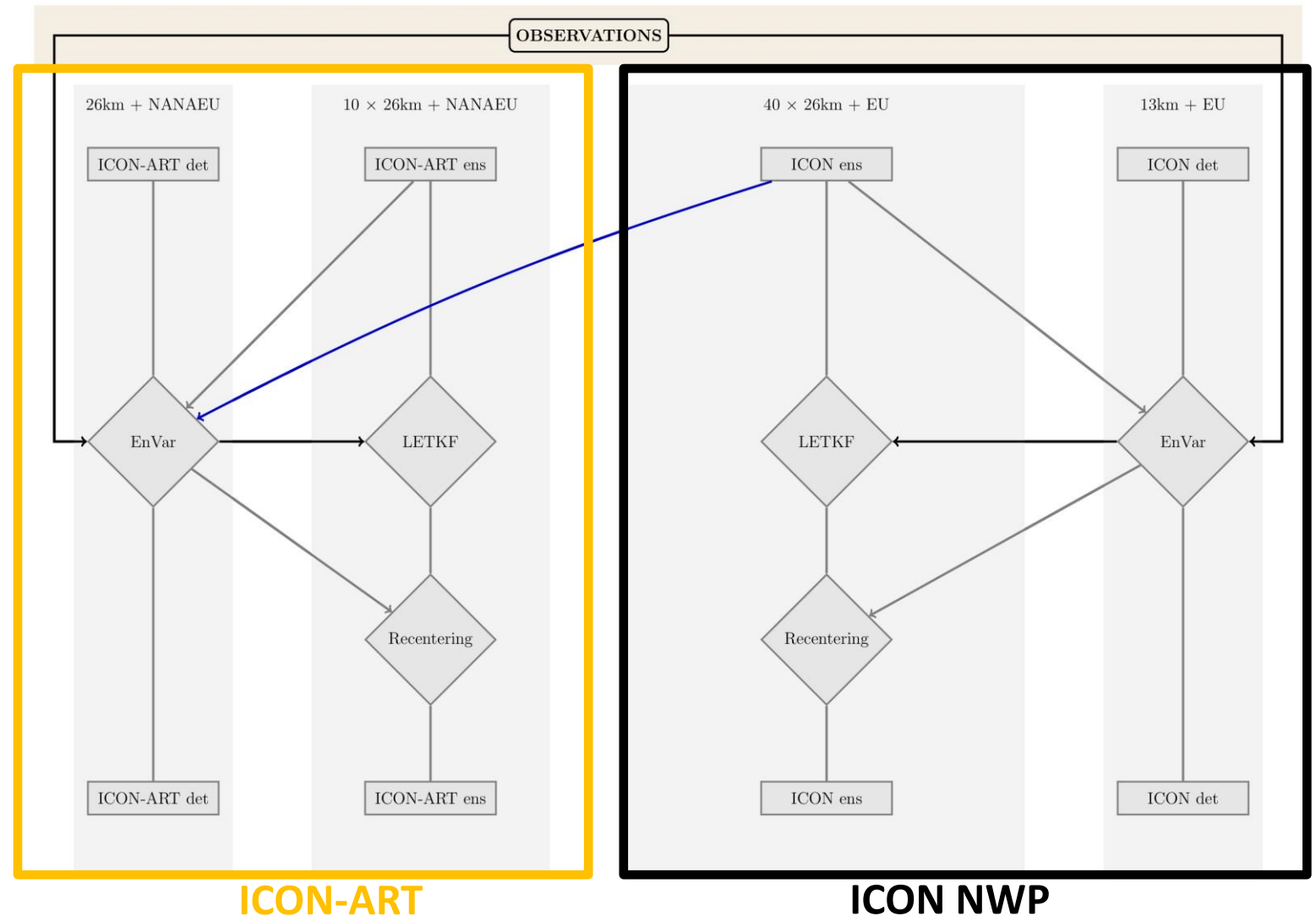


- 2nd smaller ensemble
- 2nd deterministic run
- 2nd system includes prognostic mineral dust forecasts



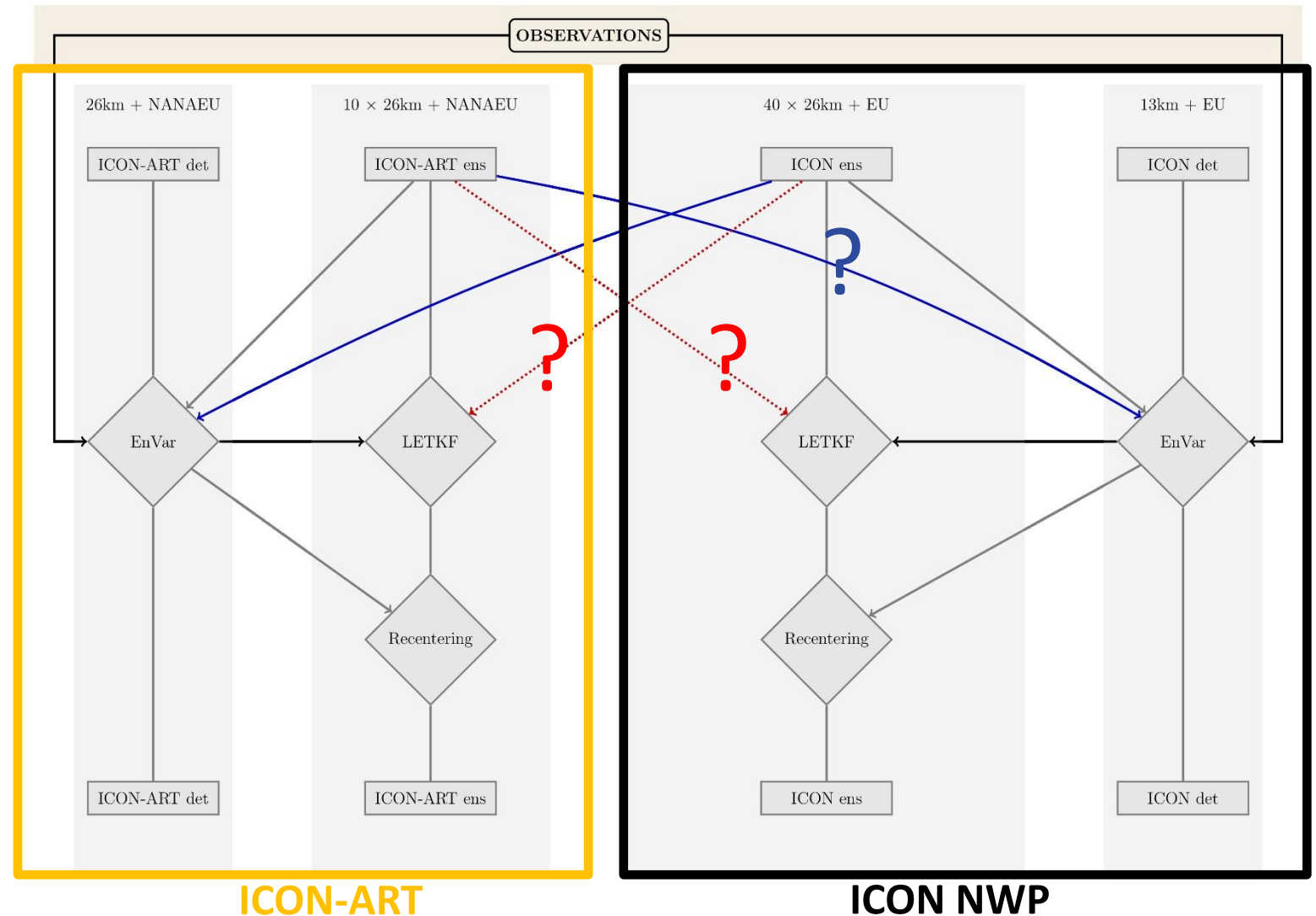
Combine ICON and ICON-ART ensembles in data assimilation for ICON-ART:

- Bigger ensemble in EnVar data assimilation (→)

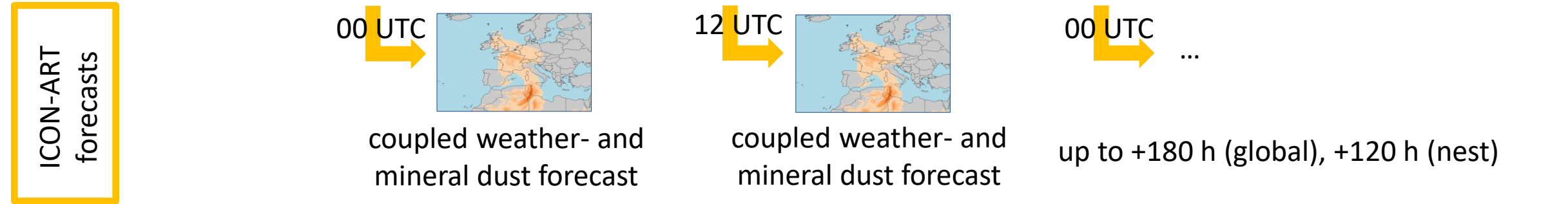
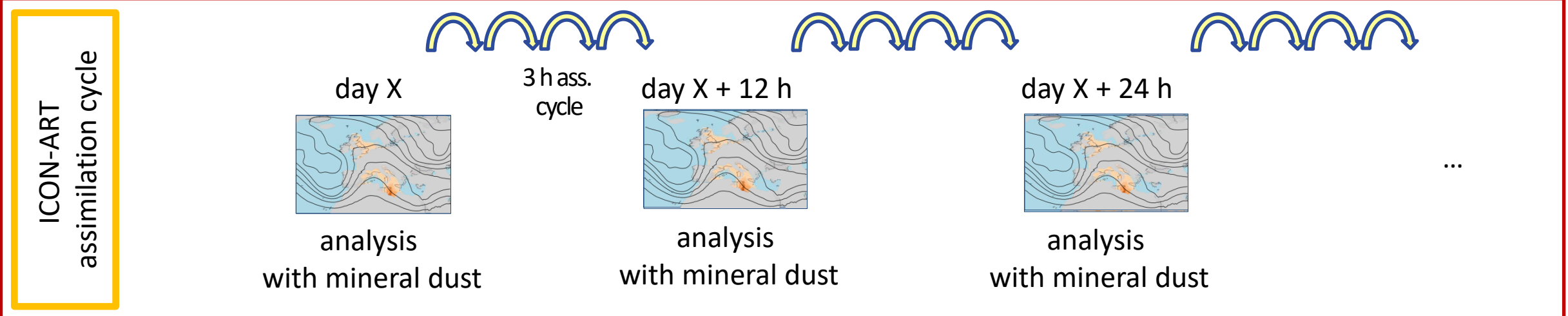


Combine ICON and ICON-ART ensembles in data assimilation for ICON-ART:

- Bigger ensemble in EnVar data assimilation (—→)
- Outlook: Optionally bigger ensemble in LETKF data assimilation (.....→)
- ?/? Maybe later ...



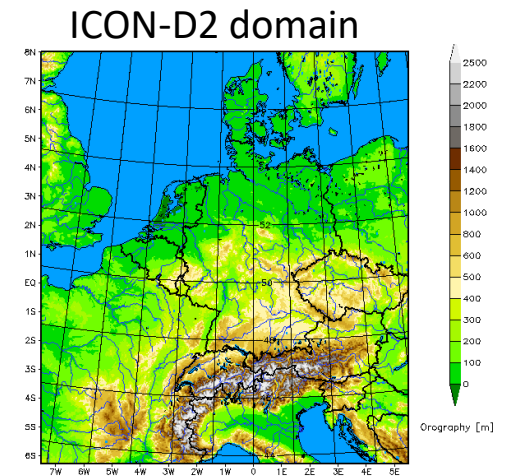
Plan: operational ICON-ART forecast at DWD (26/13 km)



first guess forecasts in the assimilation cycle are ICON-ART forecasts with prognostic mineral dust, including the interaction with the atmosphere.



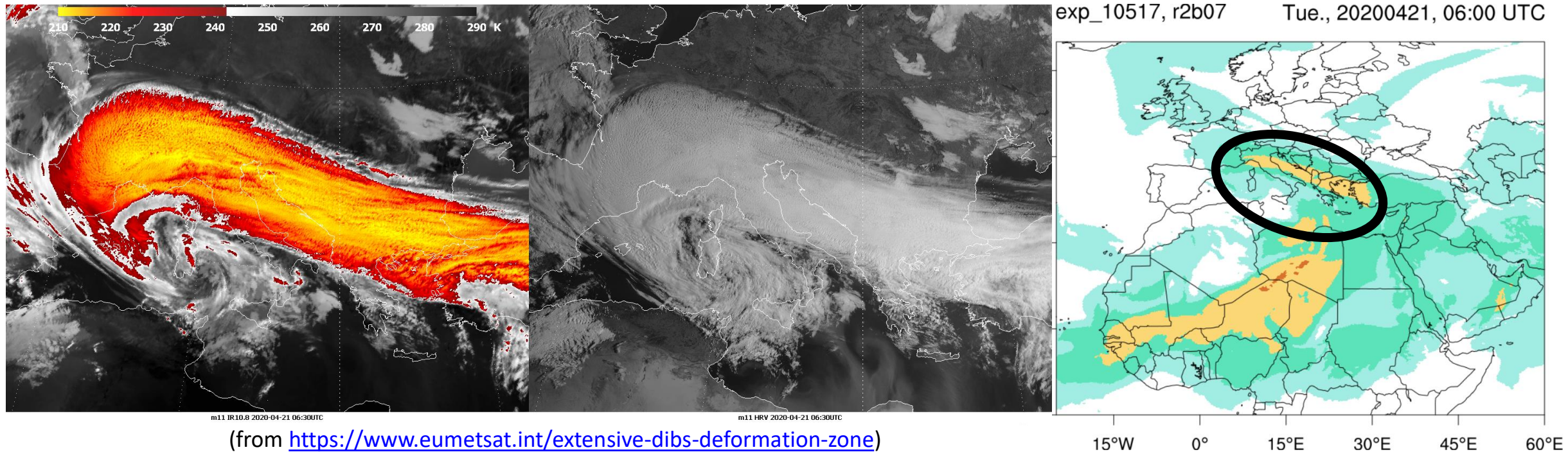
SIMULATION OF “DUSTY CIRRUS” WITH ICON-D2-ART



For more details see Seifert et al., 2023:

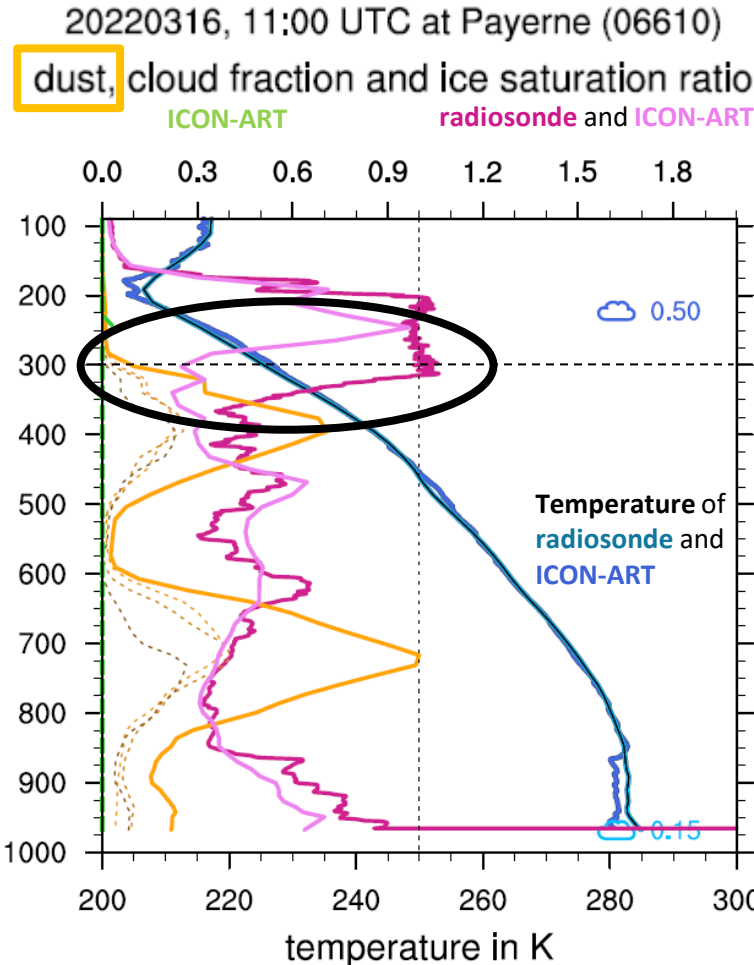
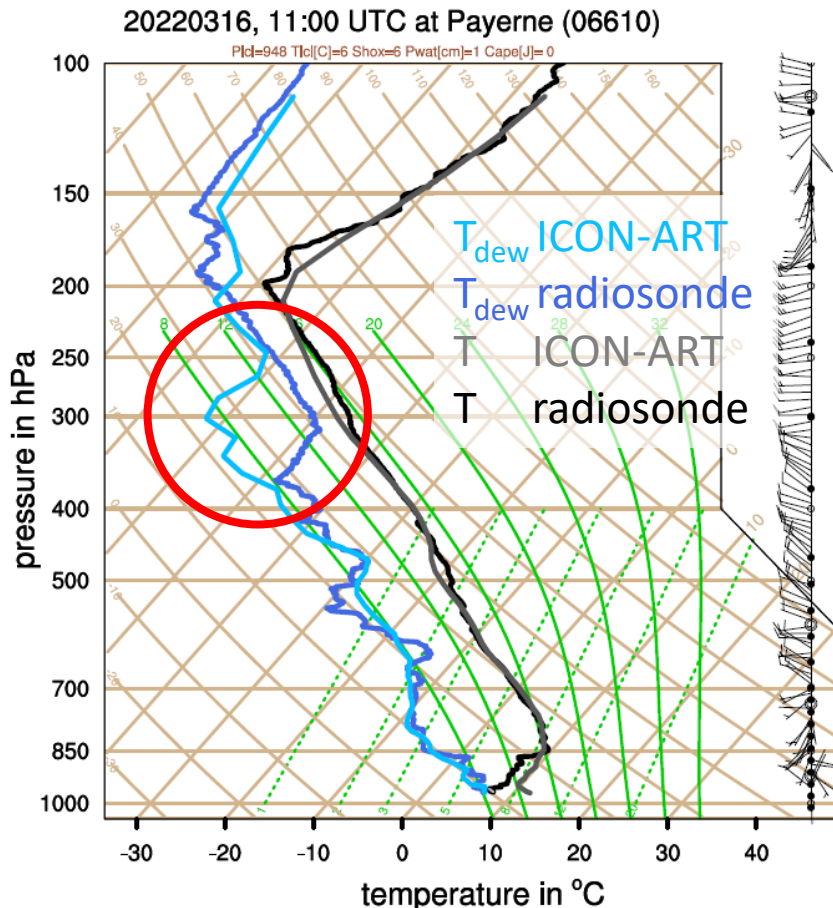
Seifert, A., Bachmann, V., Filipitsch, F., Förstner, J., Grams, C. M., Hoshyaripour, G. A., Quinting, J., Rohde, A., Vogel, H., Wagner, A., and Vogel, B.: Aerosol–cloud–radiation interaction during Saharan dust episodes: the dusty cirrus puzzle, *Atmos. Chem. Phys.*, 23, 6409–6430, <https://doi.org/10.5194/acp-23-6409-2023>, 2023.

Dusty cirrus case of 21 April 2020



- A "dusty cirrus" is an extended cirrus cloud deck with cellular structure associated with a Saharan dust event.
- It has been speculated that the dusty cirrus forms due to longwave cooling at the dust layer (Kollath 2010).
- ICON-ART does predict mineral dust at the location of the "dusty cirrus"

Radiosonde comparison for Payerne, 16 March 2022 11 UTC

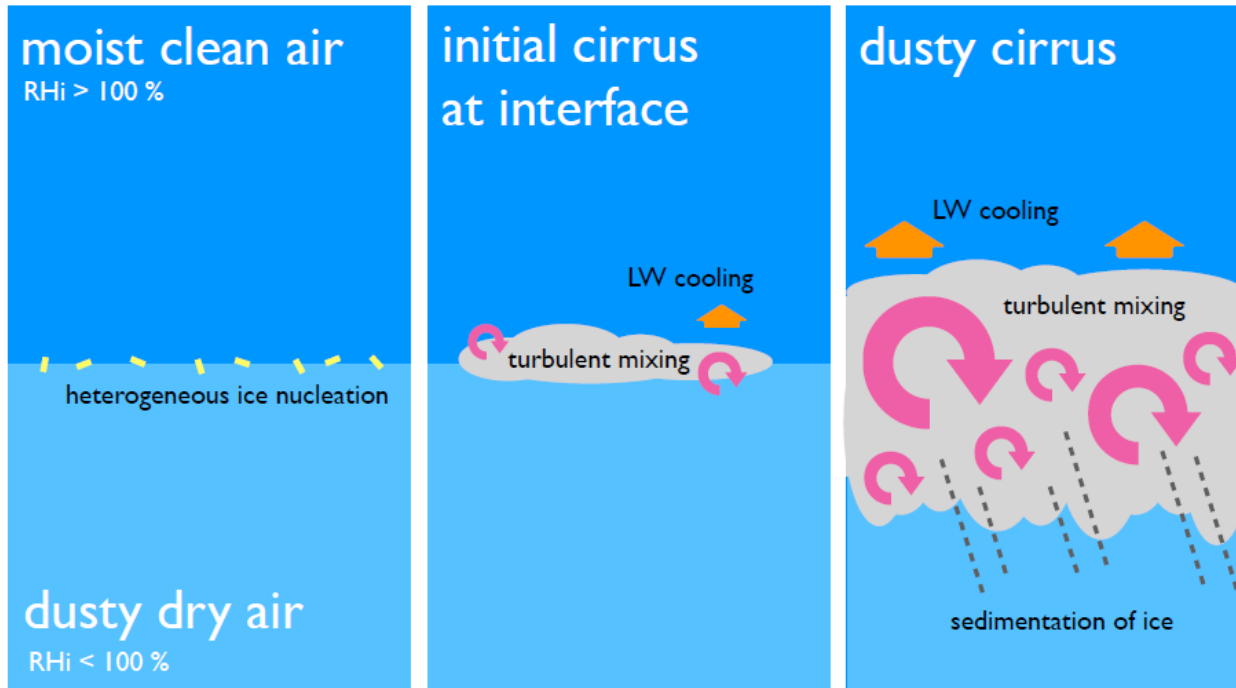


100 $\mu\text{g m}^{-3}$ normalized dust modes A, B, C in dashed lines

IR Cloud and visible reflectance of SEVIRI and ICON-ART

- Moist „anomaly“ in observed profile, 10 K error in dew point T in 300 hPa in ICON
- Cirrus layer is located above the dust, not in the dust layer

Dusty cirrus: revised conceptual model and parameterization



LW cooling at the dust layer could play a role to initiate ice nucleation at the interface, but other than it seems unnecessary to explain the formation of the cloud layer.

A simple empirical threshold-based parameterization for a sub-grid dusty cirrus:

Mass concentration of mineral dust c_{mode} with $\text{mode} \in \{\text{dustA}, \text{dustB}, \text{dustC}\}$

Ice saturation ratio $s_{\text{ice}} = p_v / p_{\text{sat,ice}}$

Temperature lapse rate

$$\Gamma_k = \left. \frac{\partial T}{\partial z} \right|_k \approx \frac{T_k - T_{k+1}}{\Delta z}$$

Dusty cirrus occurs in model level k if the following conditions are fulfilled:

$$T_k < 240 \text{ K}$$

$$c_{\text{dust},k}^* = \max_{j=k+1}^{k+N} (c_{\text{dustB},j} + 2c_{\text{dustC},j}) > 50 \mu\text{g kg}^{-3}$$

$$s_{\text{ice},k}^* = \max_{j=k}^{k+N} s_{\text{ice},j} > 0.7$$

$$\Gamma_k^* = \min_{j=k}^{k+1} \Gamma_j < -6.5 \text{ K km}^{-1}$$

with $N = 4$ corresponding to a vertical depth of approximately 1500 m.

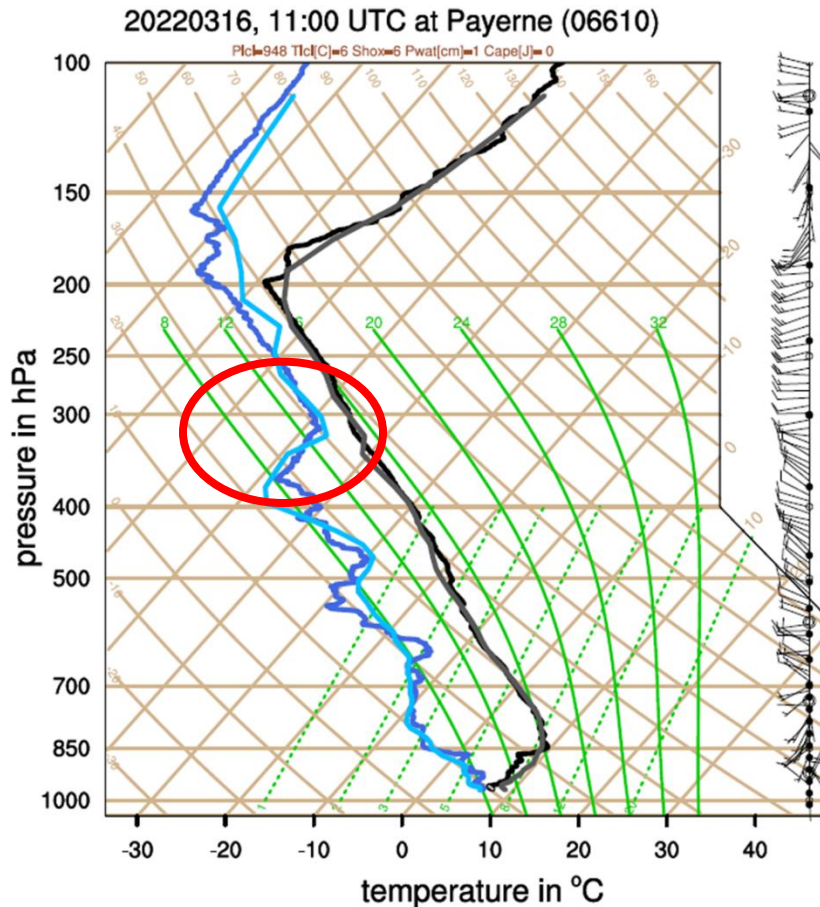
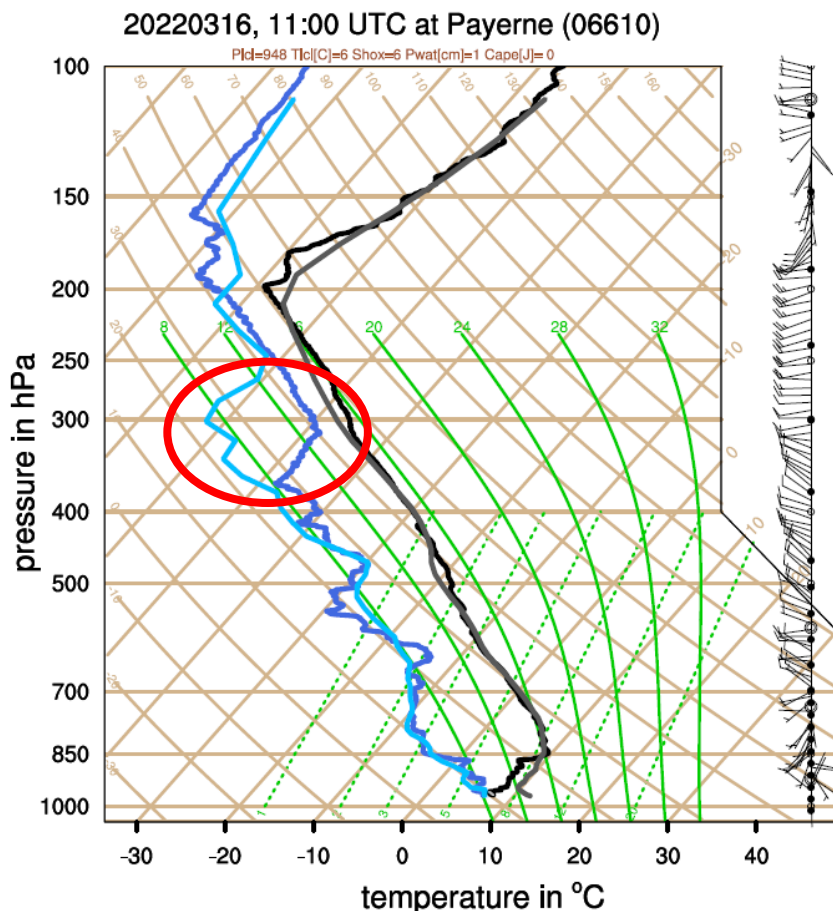
Most surprising is the very low RH_i threshold to initiate the cirrus formation.

Radiosonde comparison for Payerne, 16 March 2022 11 UTC



without "dusty cirrus" scheme

with "dusty cirrus" scheme

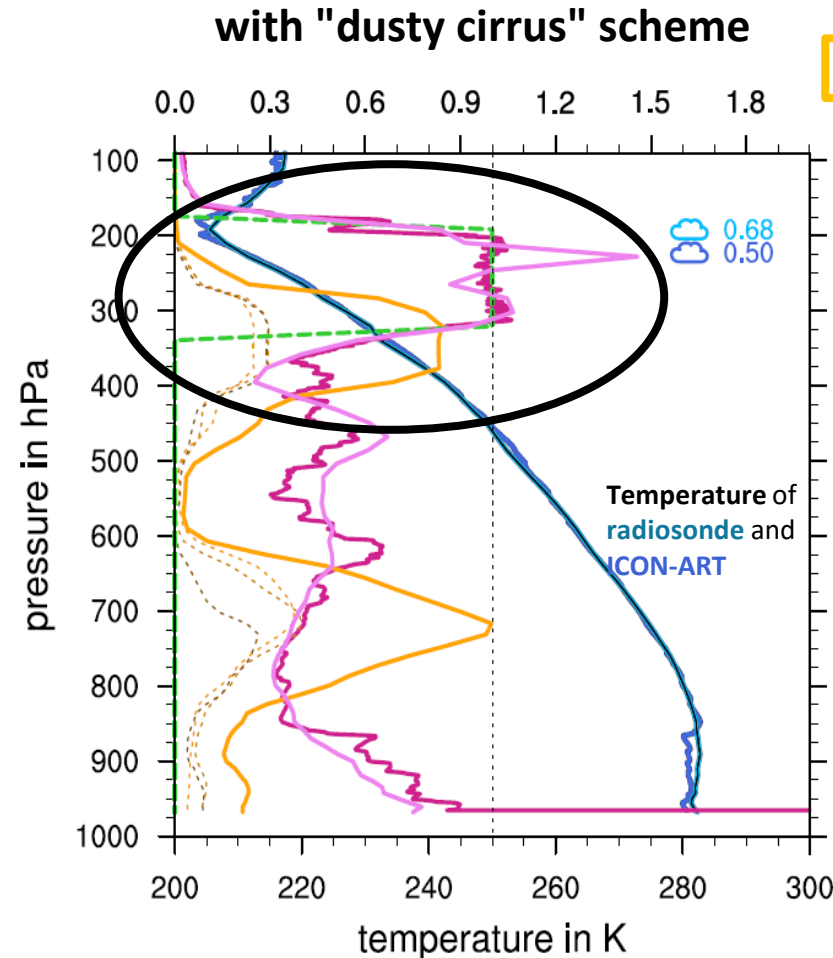
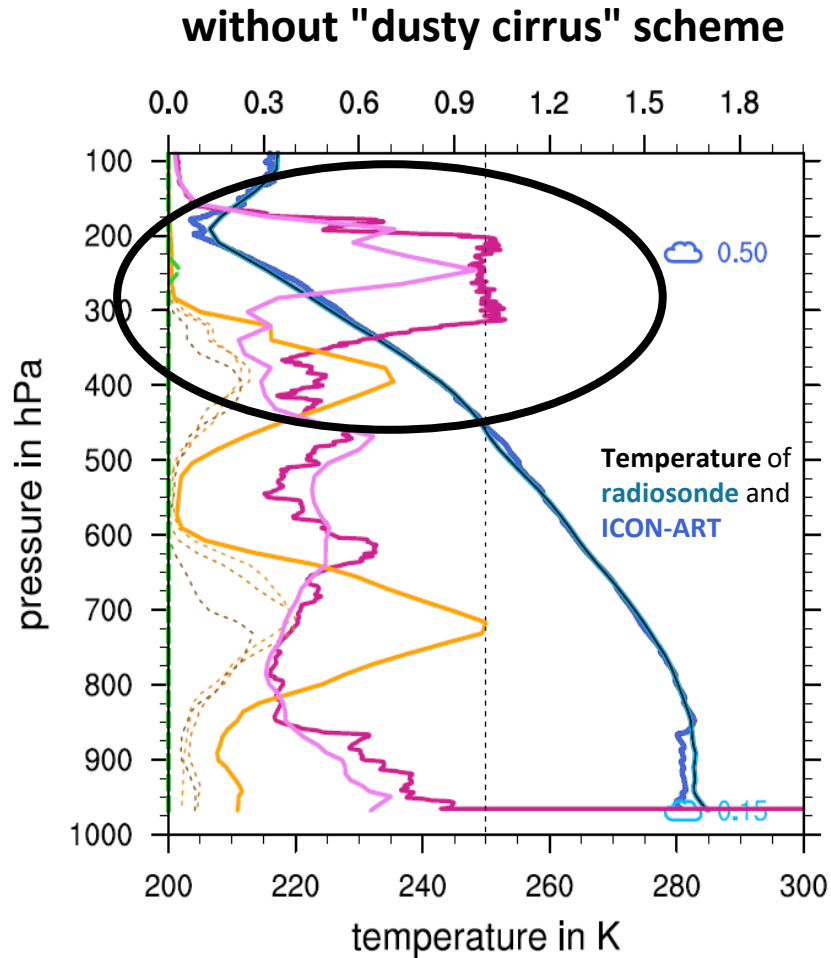


Moist "anomaly" in observed profile, 10 K error in T_{dew} in ICON without "dusty cirrus" scheme

T_{dew} ICON-ART
 T_{dew} radiosonde
T ICON-ART
T radiosonde



Radiosonde comparison for Payerne, 16 March 2022 11 UTC



20220316, 11:00 UTC at Payerne (06610)
dust, cloud fraction and ice saturation ratio
ICON-ART radiosonde and ICON-ART

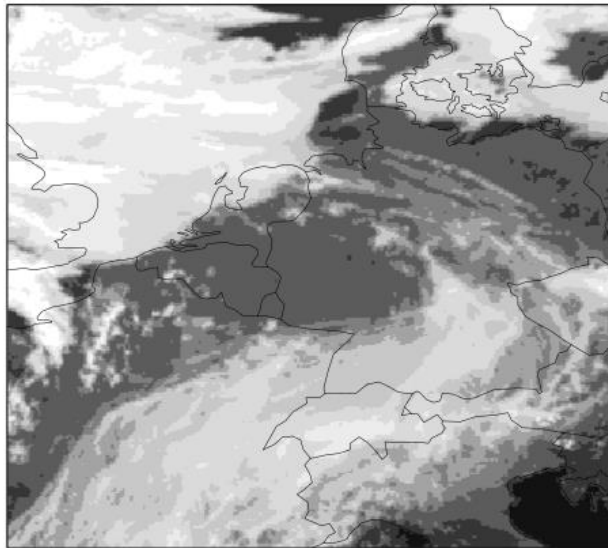
100 $\mu\text{g m}^{-3}$ normalized Dust mode A, B, C in dashed lines

IR Cloud and visible reflectance of SEVIRI and ICON-ART

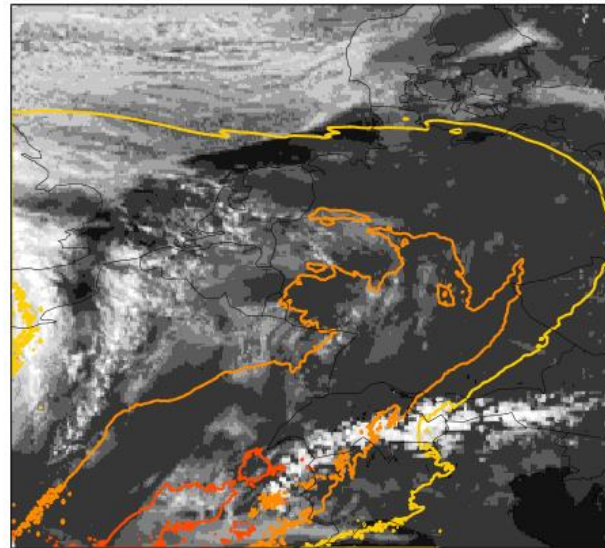
Cirrus layer is located above the dust, not in the dust layer!



MSG-SEVIRI

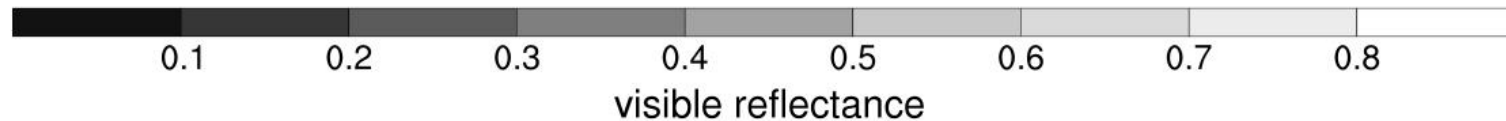


ACI

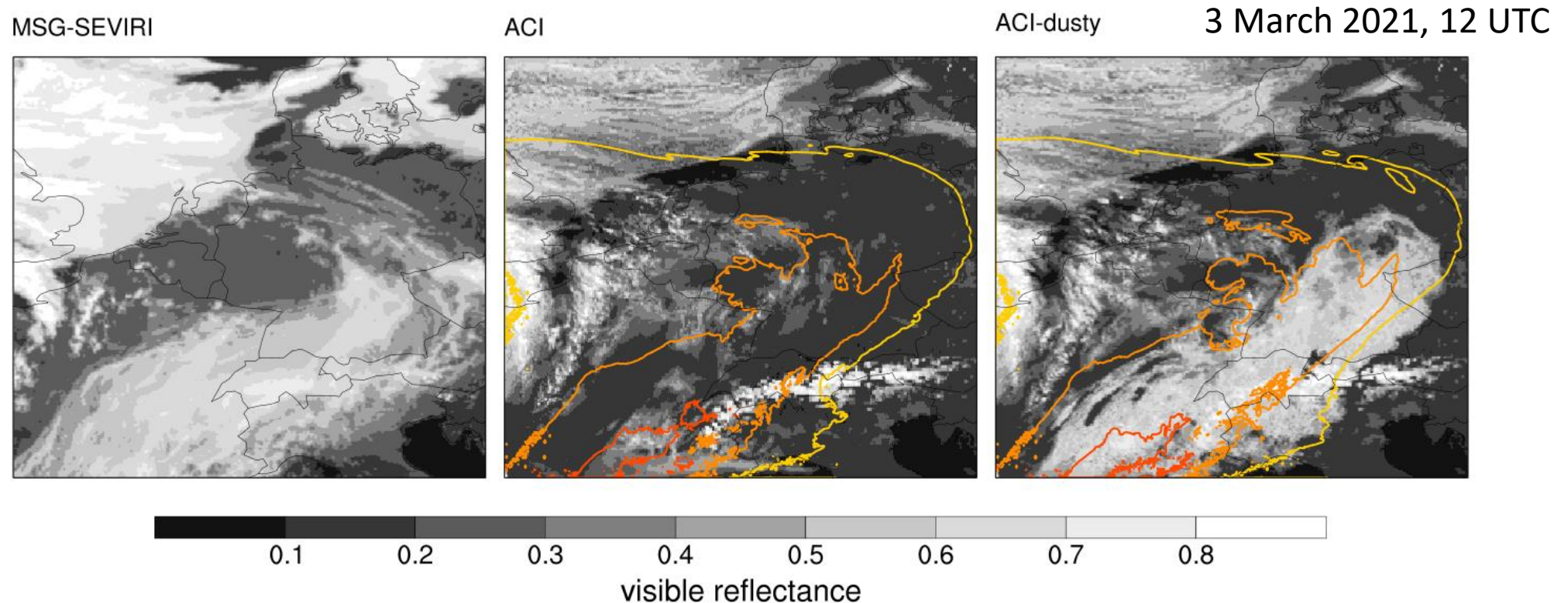


3 March 2021, 12 UTC

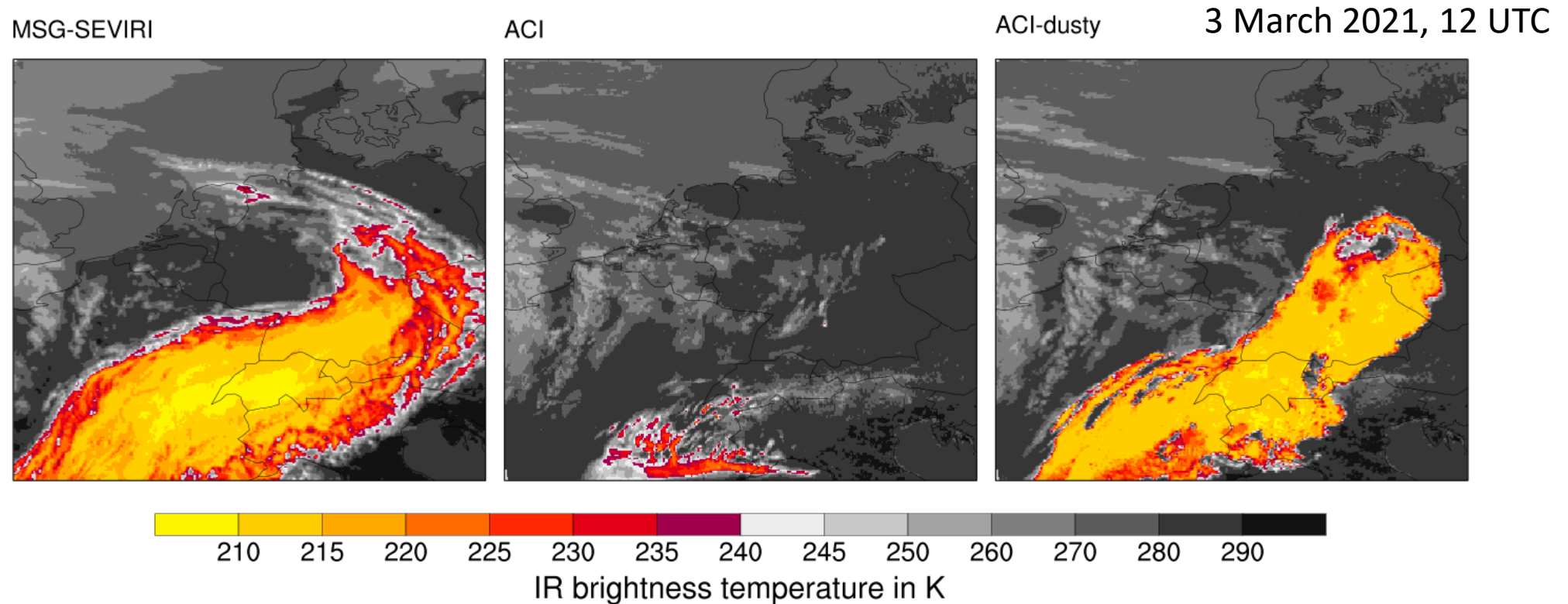
Isolines: mineral dust AOD predicted by ICON-D2-ART (interval of 0.2 starting at 0.1)



- ICON and ICON-ART miss the cirrus cloud deck associated with the dusty air mass
- Even in ICON-D2-ART a special developed parametrization is needed to simulate the “dusty cirrus”



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SUMMARY AND OUTLOOK

Summary

- ICON-ART with prognostic mineral dust quasi-operational at DWD since Dec. 2017
- ICON-ART ensemble experiments, combination of ICON-ART and ICON ensemble
- ICON-D2-ART with “Dusty Cirrus” parameterization

Outlook

- ICON-ART with prognostic mineral dust soon operational (plan: Q4 2023)
- ART parameter perturbations in ICON-ART ensemble
- “Dusty Cirrus” parameterization in global experiments
- additional aerosol types sea salt and biomass burning aerosol in quasi-operational experiments