Forecasting the reduction in photovoltaic power production during Saharan dust outbreaks

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Deutscher Wetterdienst, Research and Development, Physical Processes

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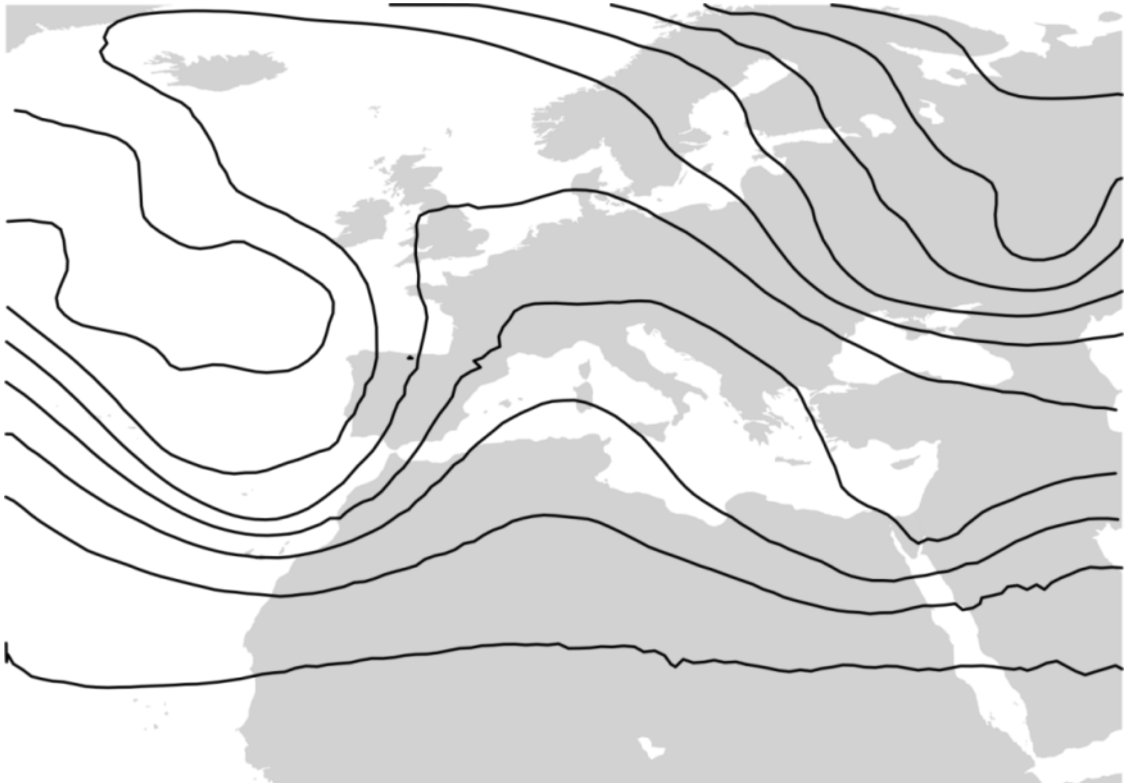
12-16 September, 2016

Outline

- Motivation
- Project members
- Project goals
- Modelling system ICON-ART
- First sensitivity studies

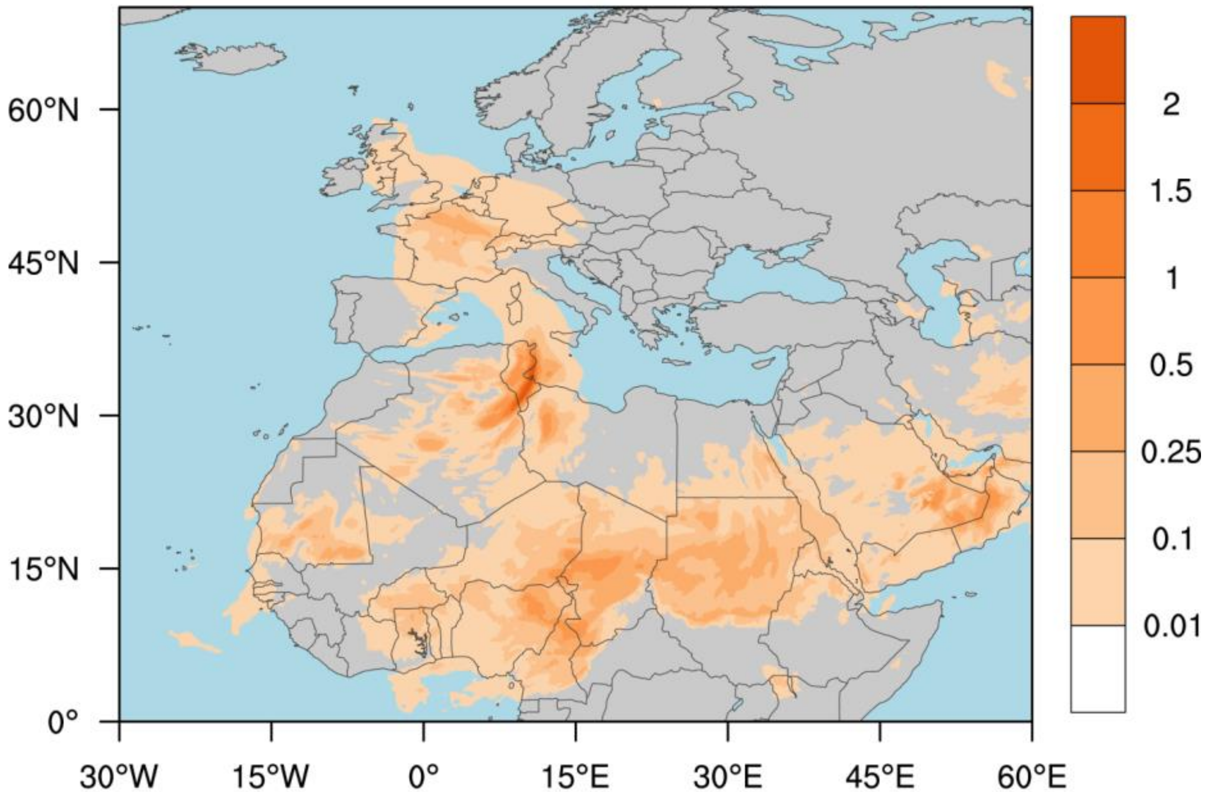
Motivation

500 hPa Geopotential, 02.04.2014



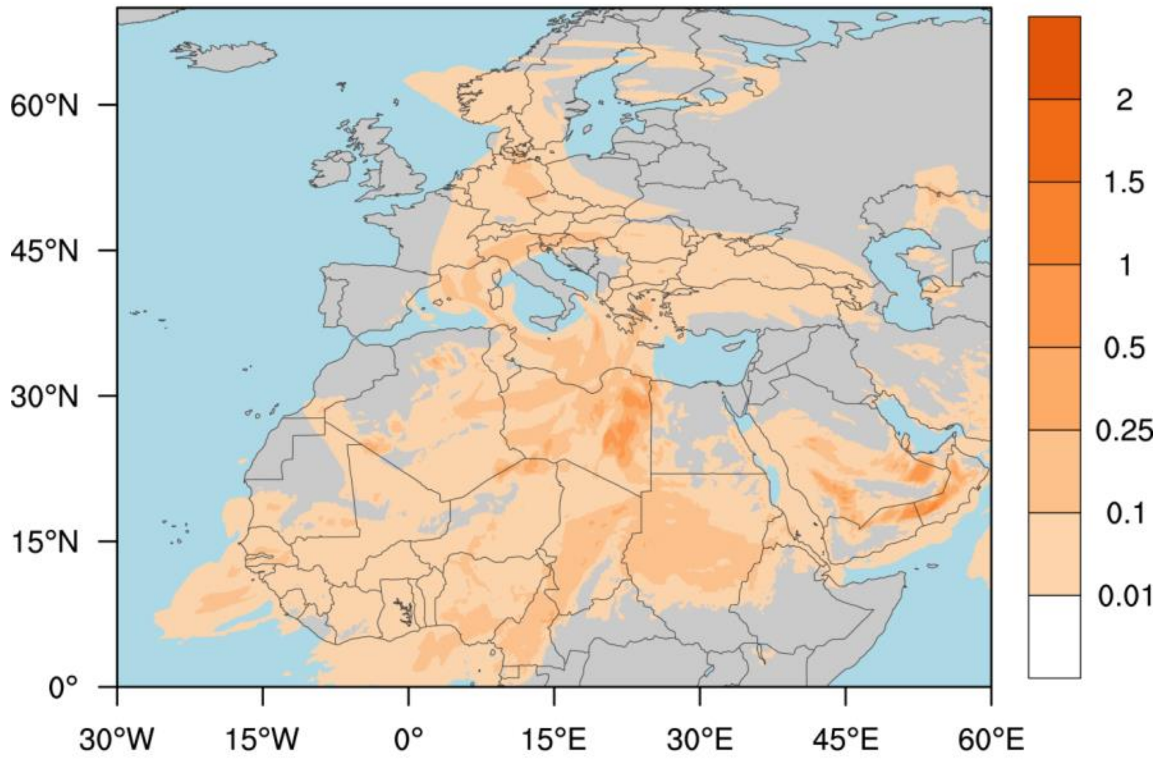
Motivation

Simulated Aerosol Optical Depth (550 nm)
03.04.2014, 18:00 UTC

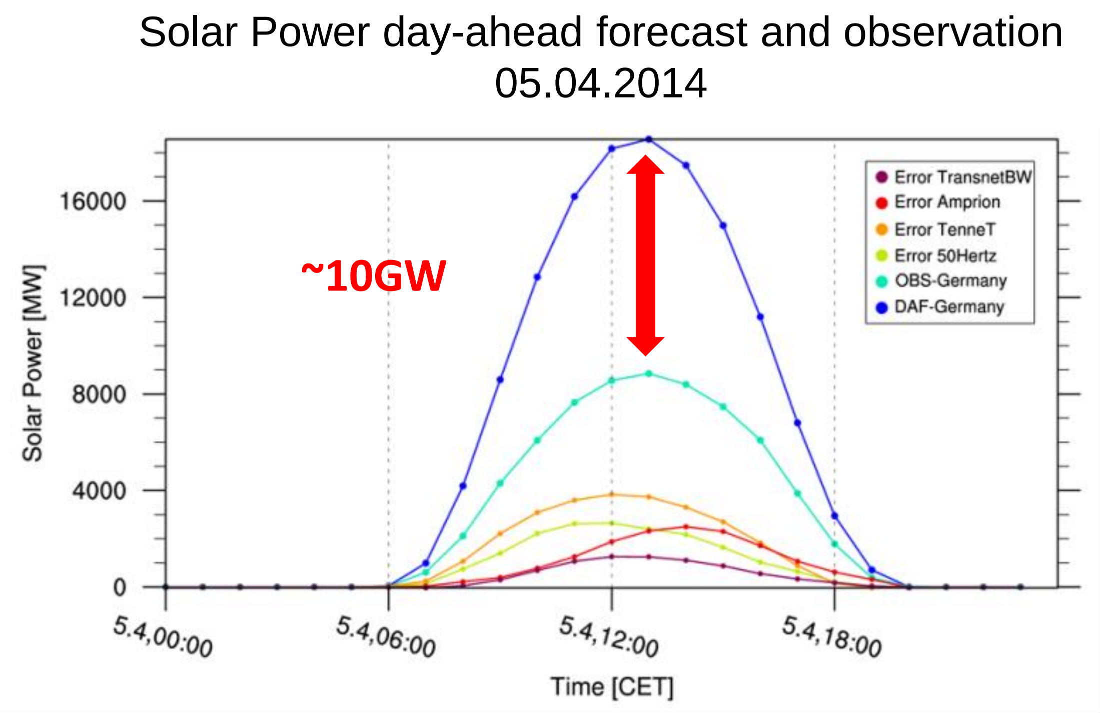


Motivation

Simulated Aerosol Optical Depth (550 nm)
05.04.2014, 12:00 UTC

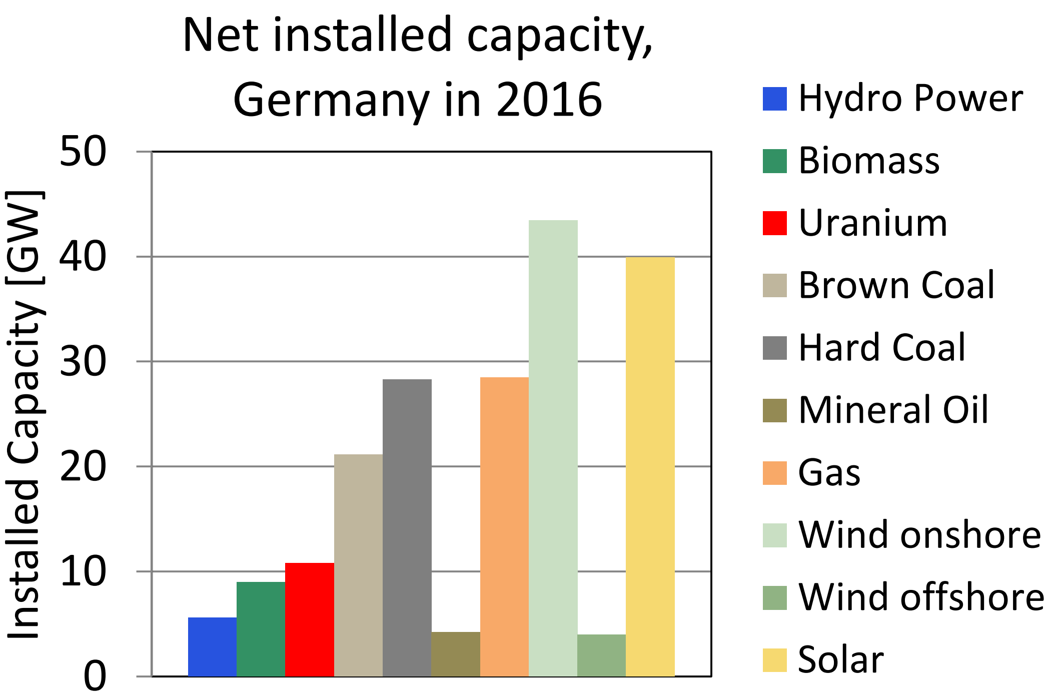


Motivation



source: https://transparency.entsoe.eu/

Photovoltaic (PV) Power in Germany



PV in Germany, 2015:

➔ 1,5 Million PV-panels

➔ ~ 40 GW net installed capacity

➔ 7,5 % of net energy demand covered by PV

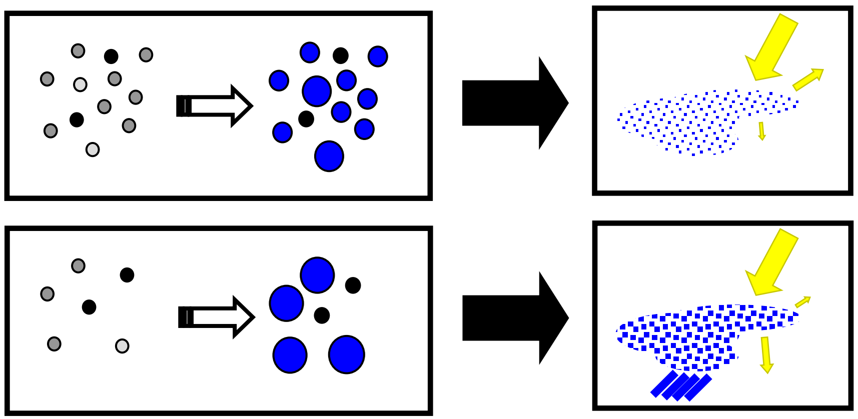
➔ on sunny days, up to 50 % of instantaneous energy demand covered by PV

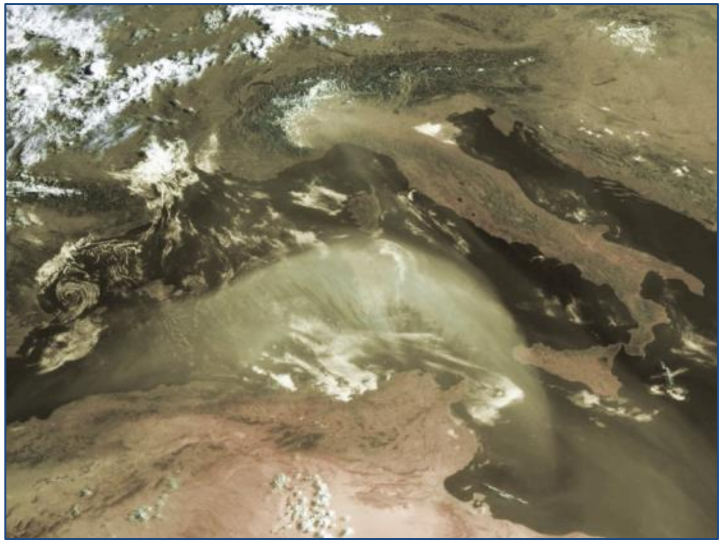
Source: https://www.energy-charts.de/

Motivation

Challenge of Saharan Dust Outbreaks for PV-power forecasting:

→ NWP Forecast errors

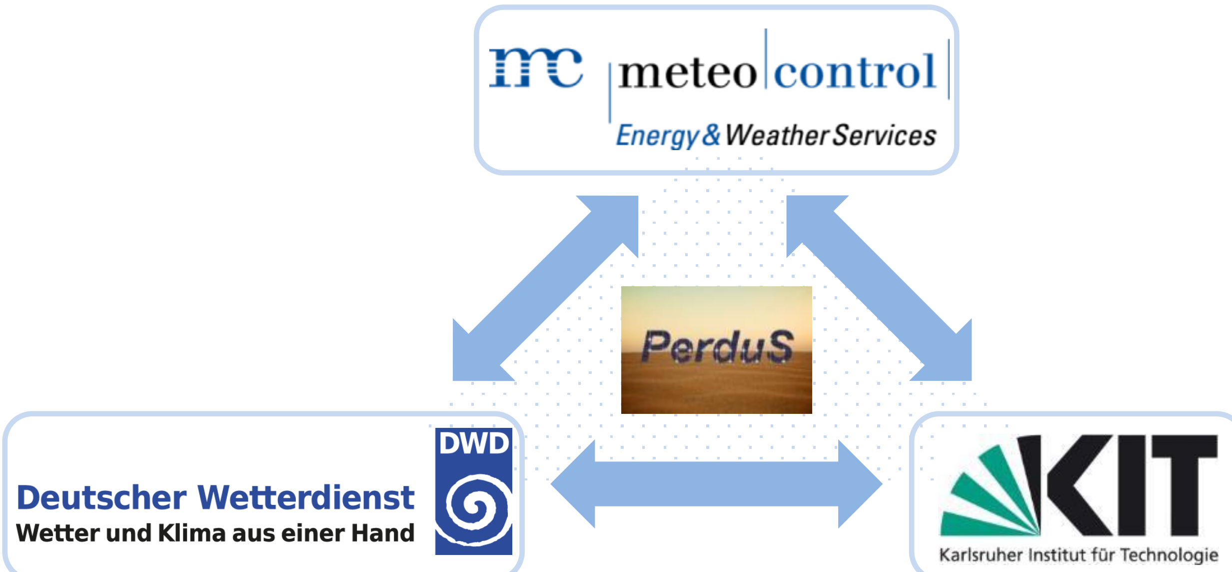




source: http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20050728_dust/20050728_dust.html

→ Polluted PV-modules

Project Members



Federal Ministry
for Economic Affairs
and Energy

4 years: 01.03.2016 – 29.02.2020

DWD: 3 scientists, KIT: 2 scientists, Meteocontrol: 19,5 PM

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Project Goals

Main objective:

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

Therefore:

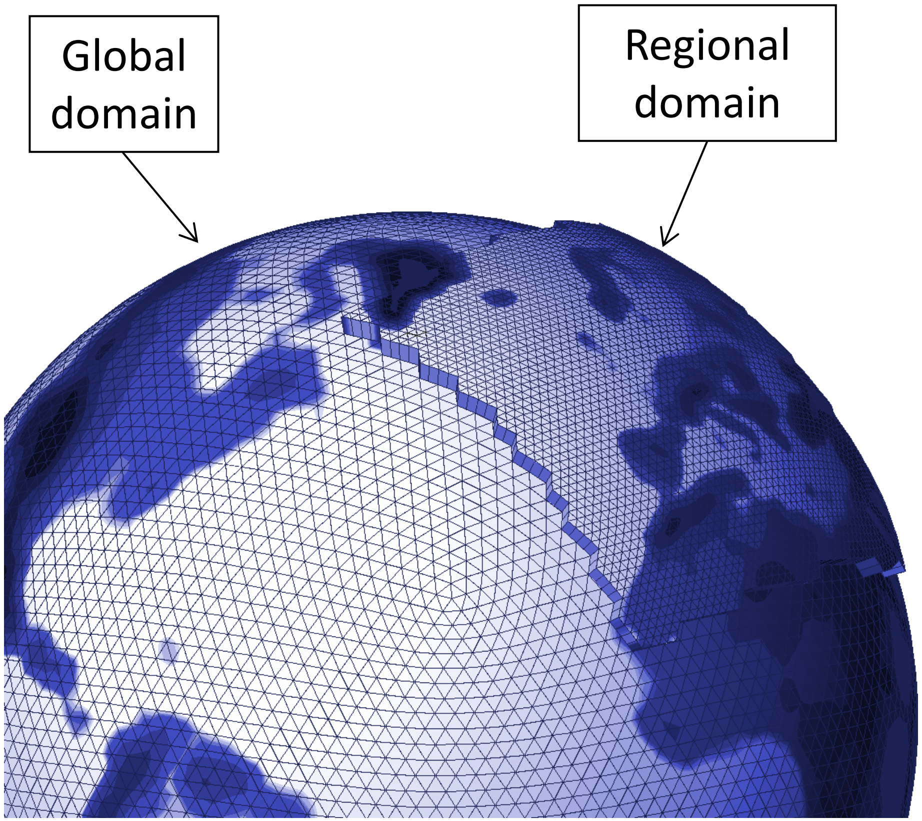
→ Use and improvement of the model system ICON-ART
- dust emission
- optical properties of mineral dust
- washout / deposition of aerosols

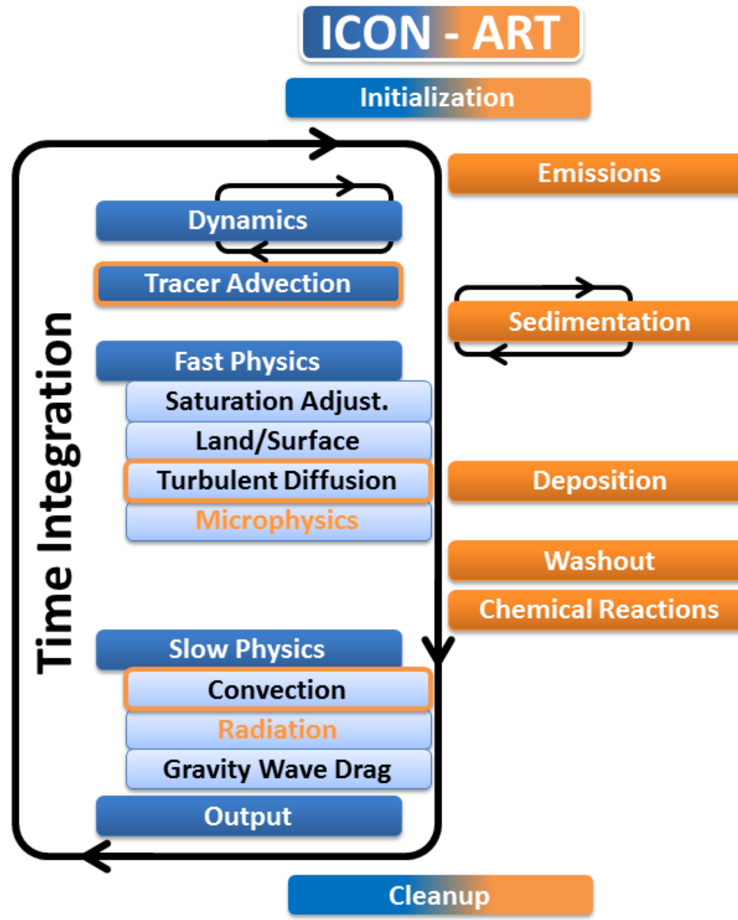
→ High quality observations

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

→ Quasi-Operational application

ICON and ART (Aerosols and Reactive Trace Gases)





For ICON see Zängl et. al. 2015

For ICON-ART see Rieger et. al. 2015

Mineral Dust in ICON-ART:

- ➔ Polydisperse aerosols
- ➔ Modal approach: 3 modes
- ➔ Lognormal distributions
- ➔ Additional prognostic equations for:
  - ➔ Specific number
  - ➔ Mass mixing ratio
- ➔ +6 equations

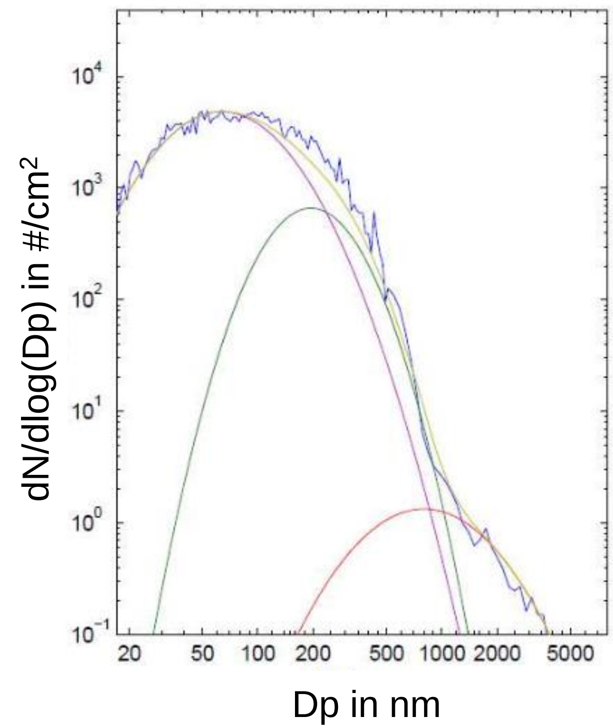
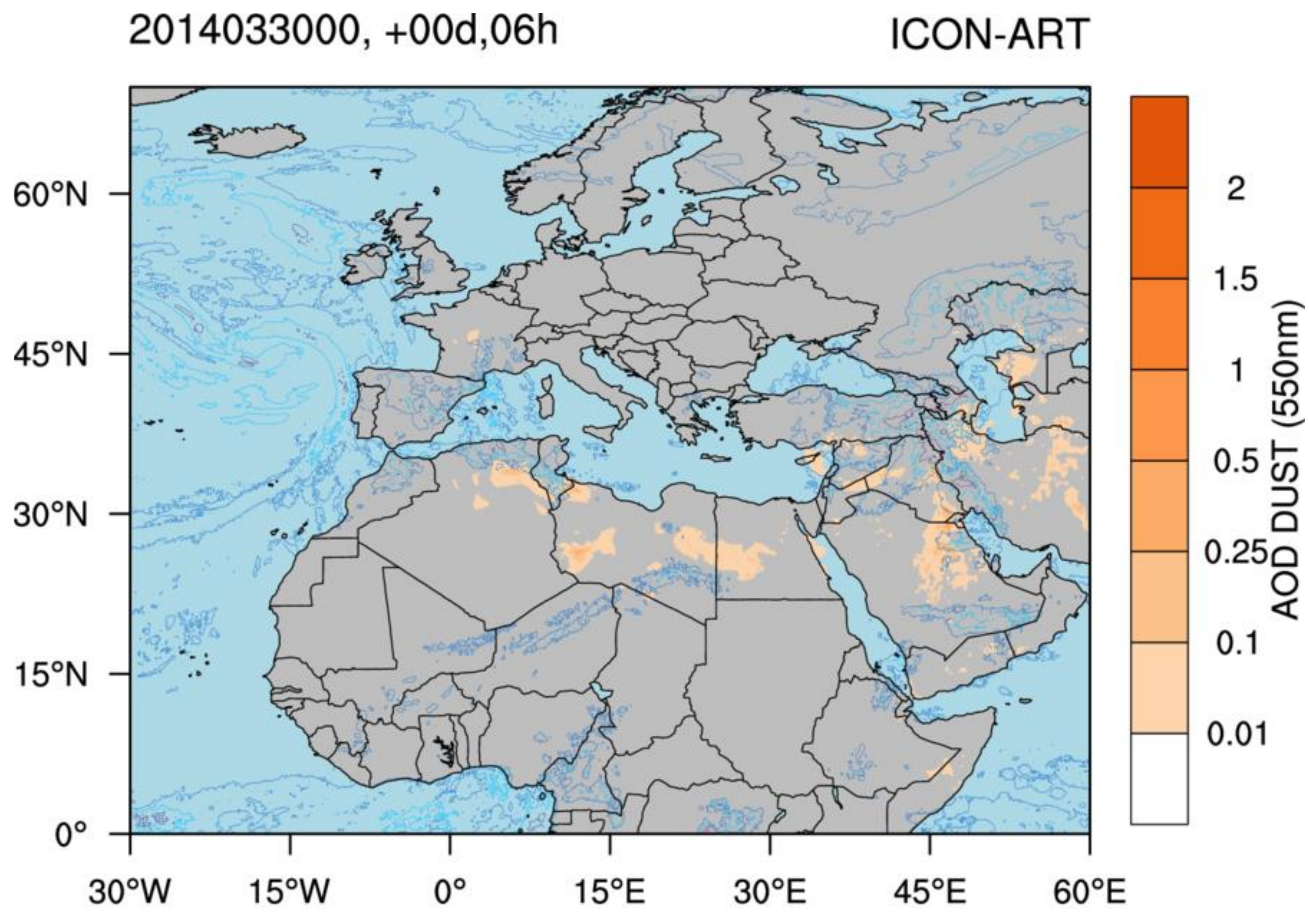


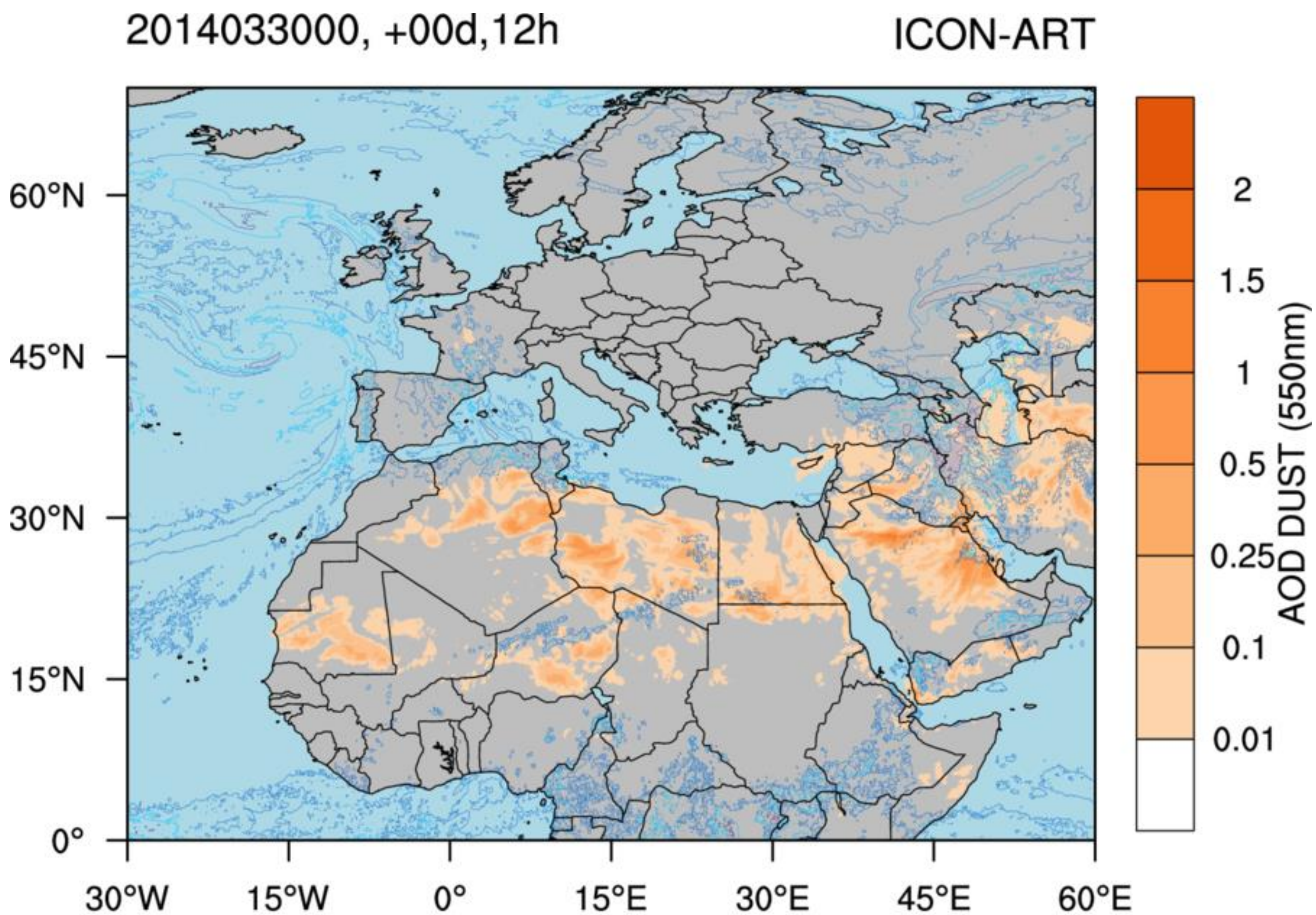
Figure 4.28 in Versick, 2006

Study 30.03.2014 – 06.04.2014



Precipitation in mm: • 0.01 • 1 • 5 • 10 • 20 • 30

Study 30.03.2014 – 06.04.2014



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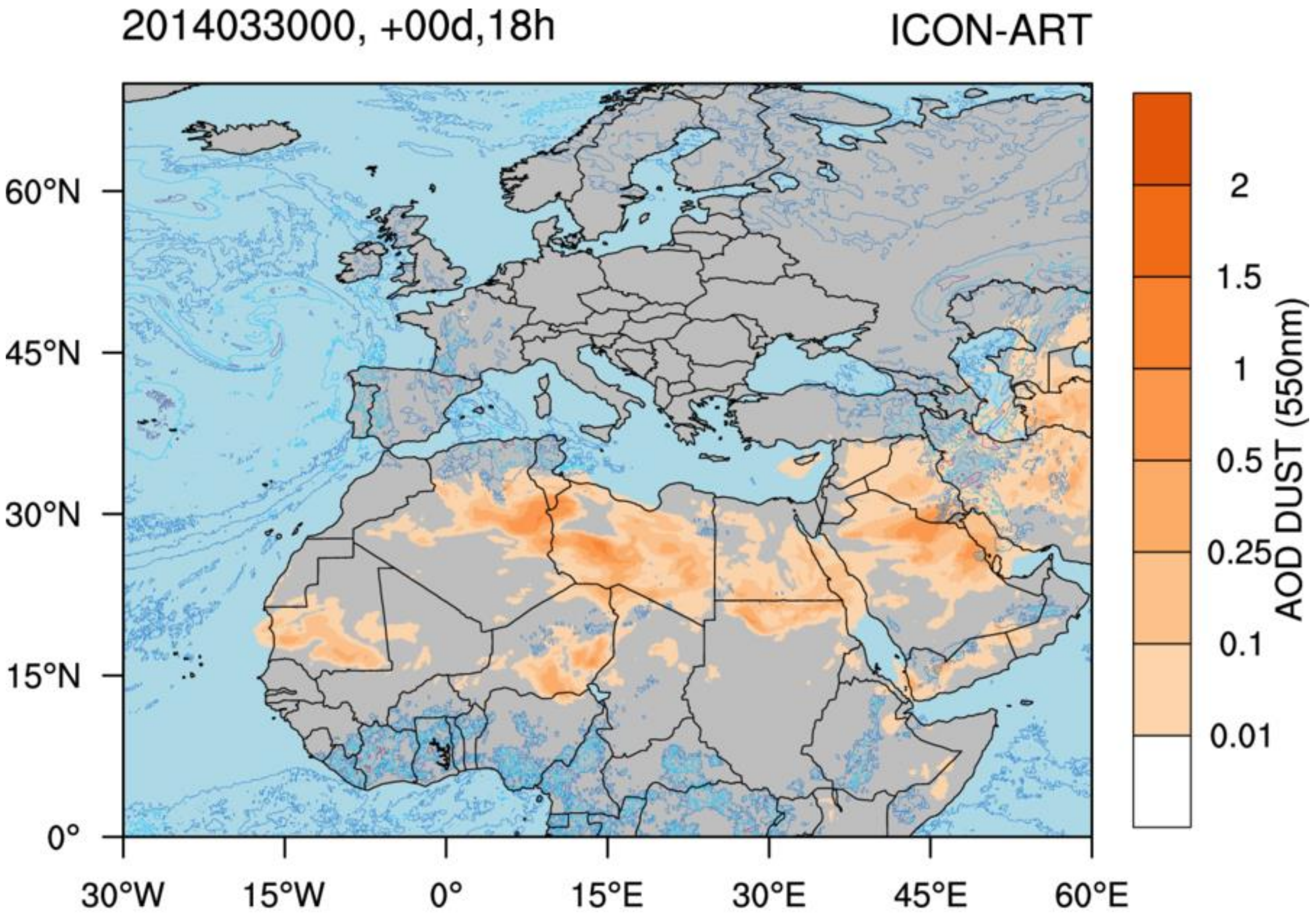

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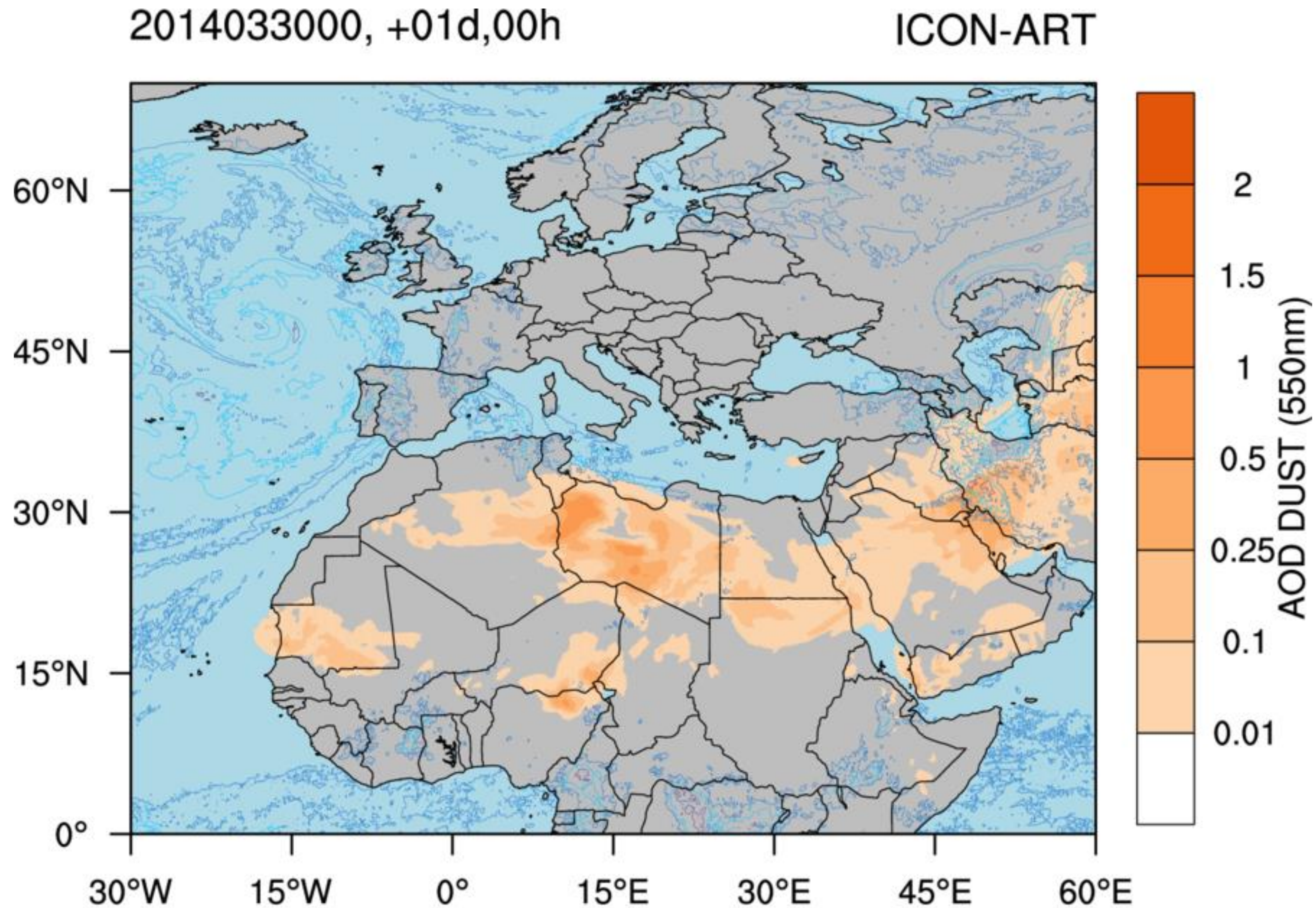
Study 30.03.2014 – 06.04.2014

Deutscher Wetterdienst
Wetter und Klima aus einer Hand



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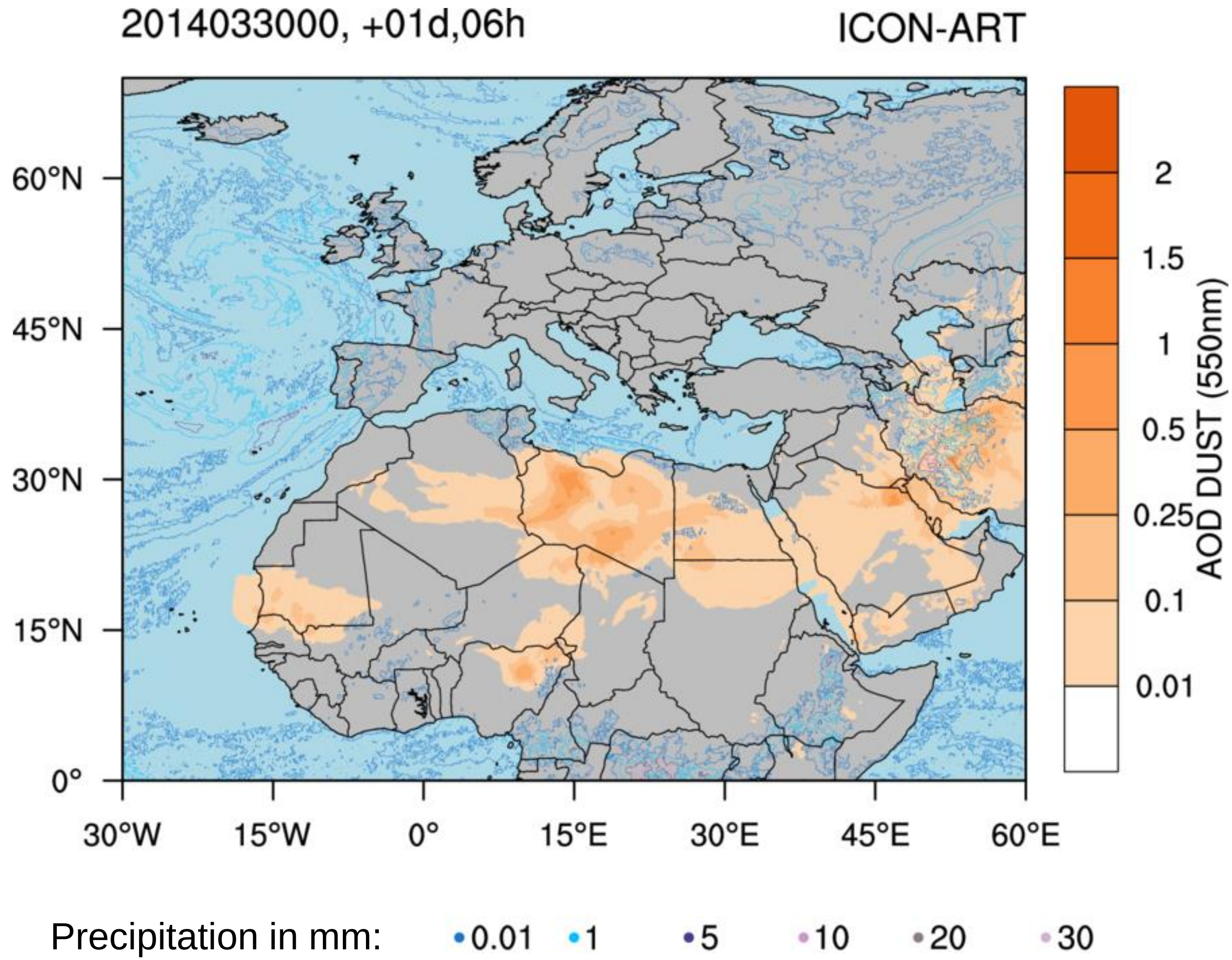

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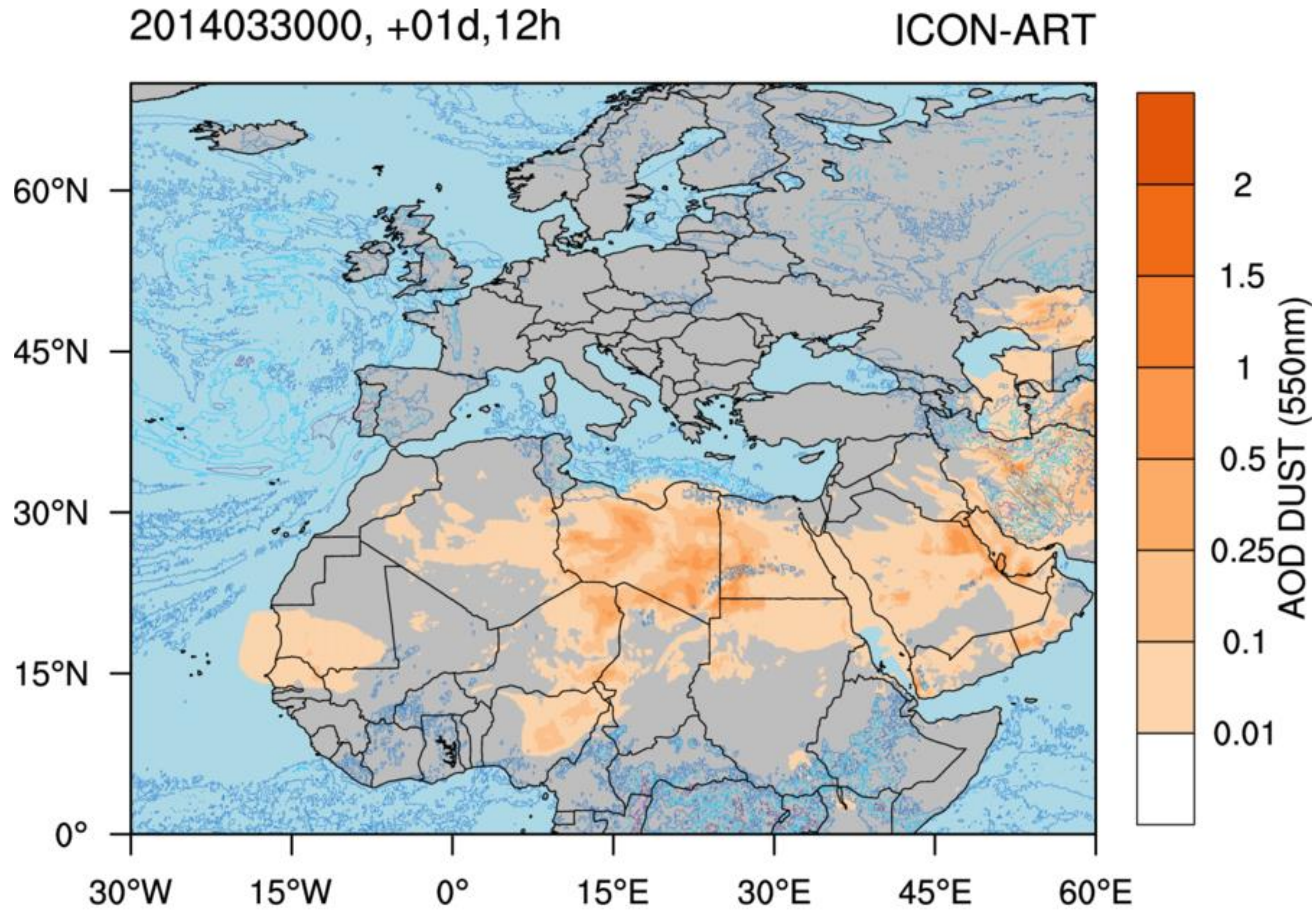

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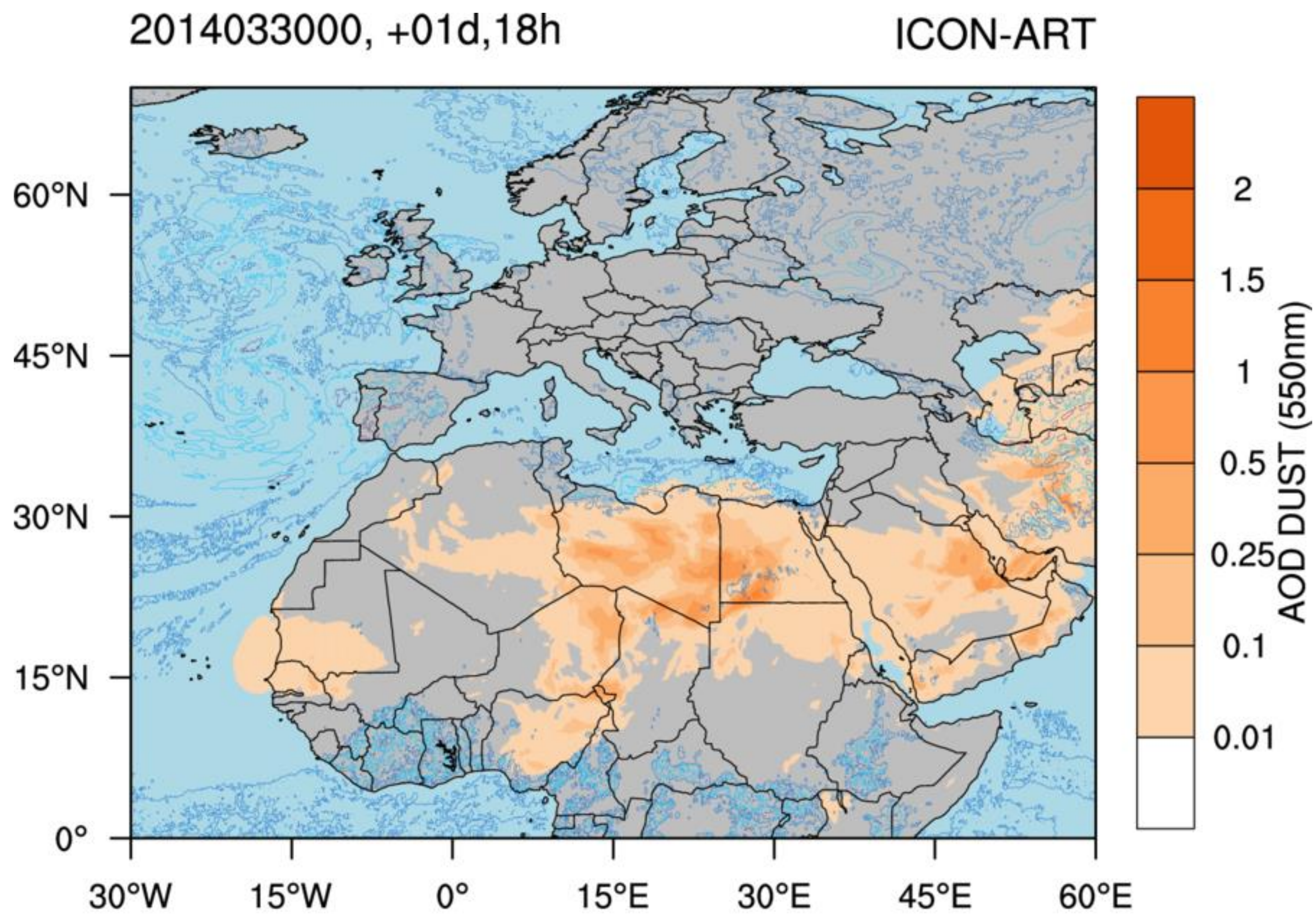

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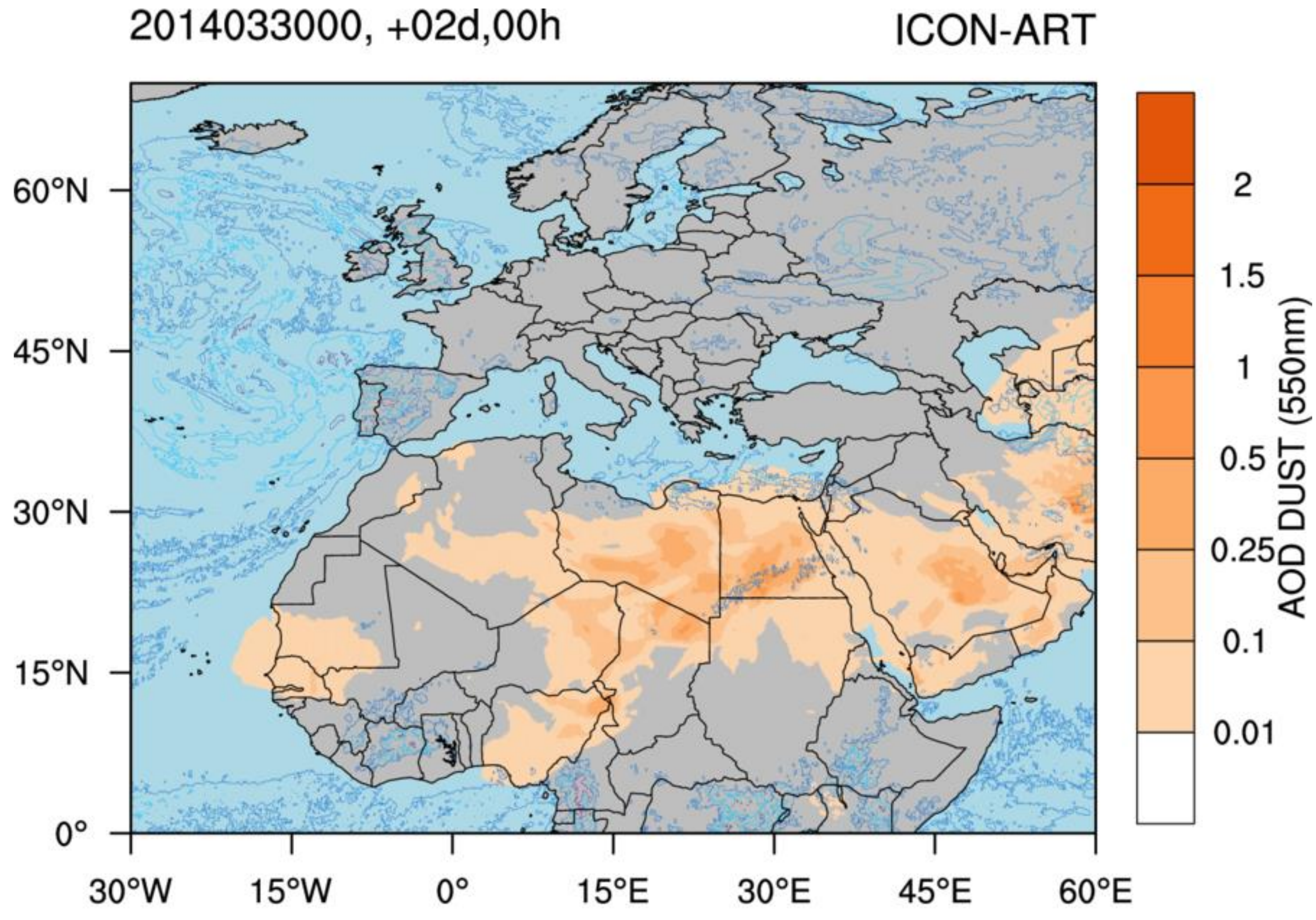

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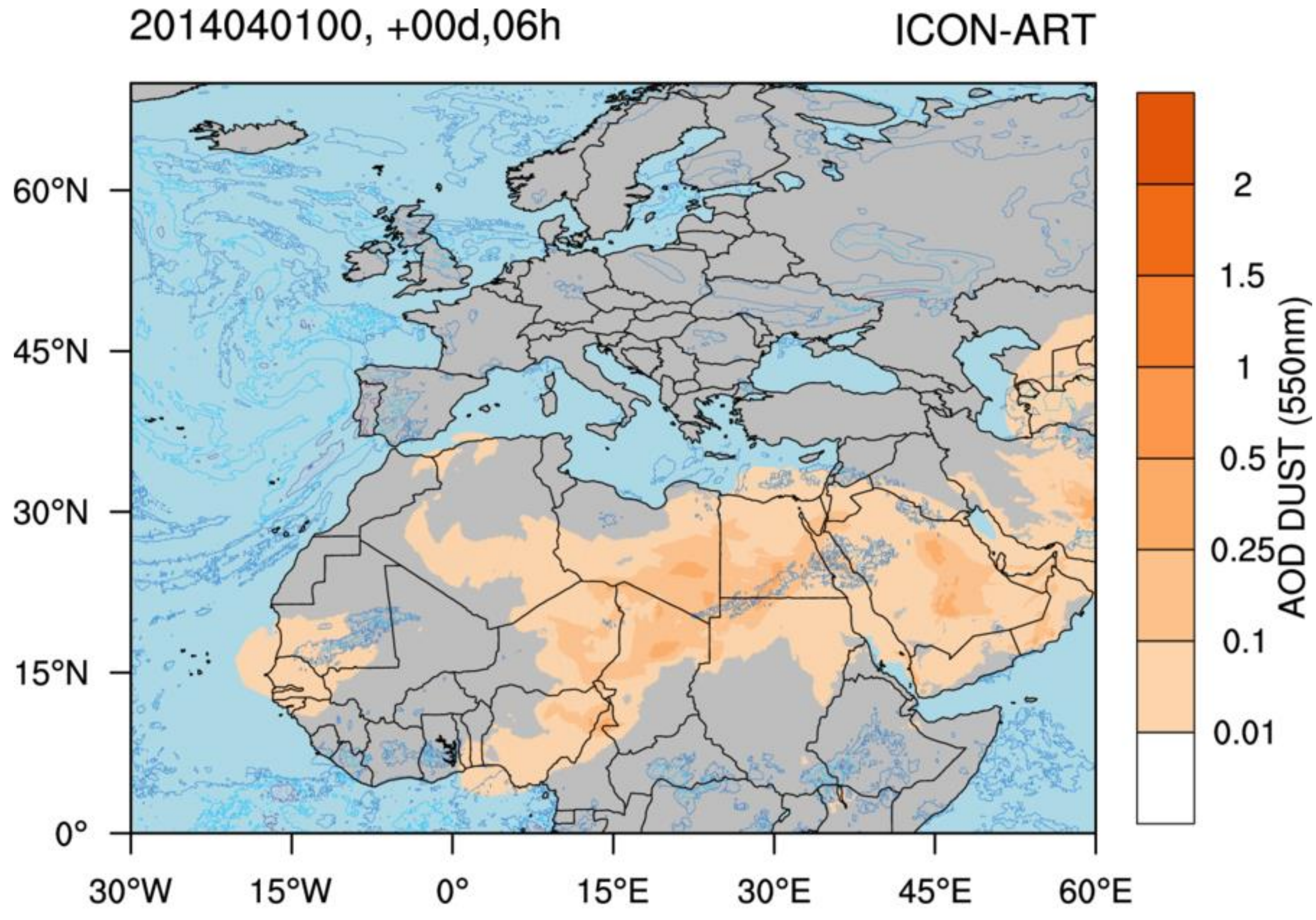

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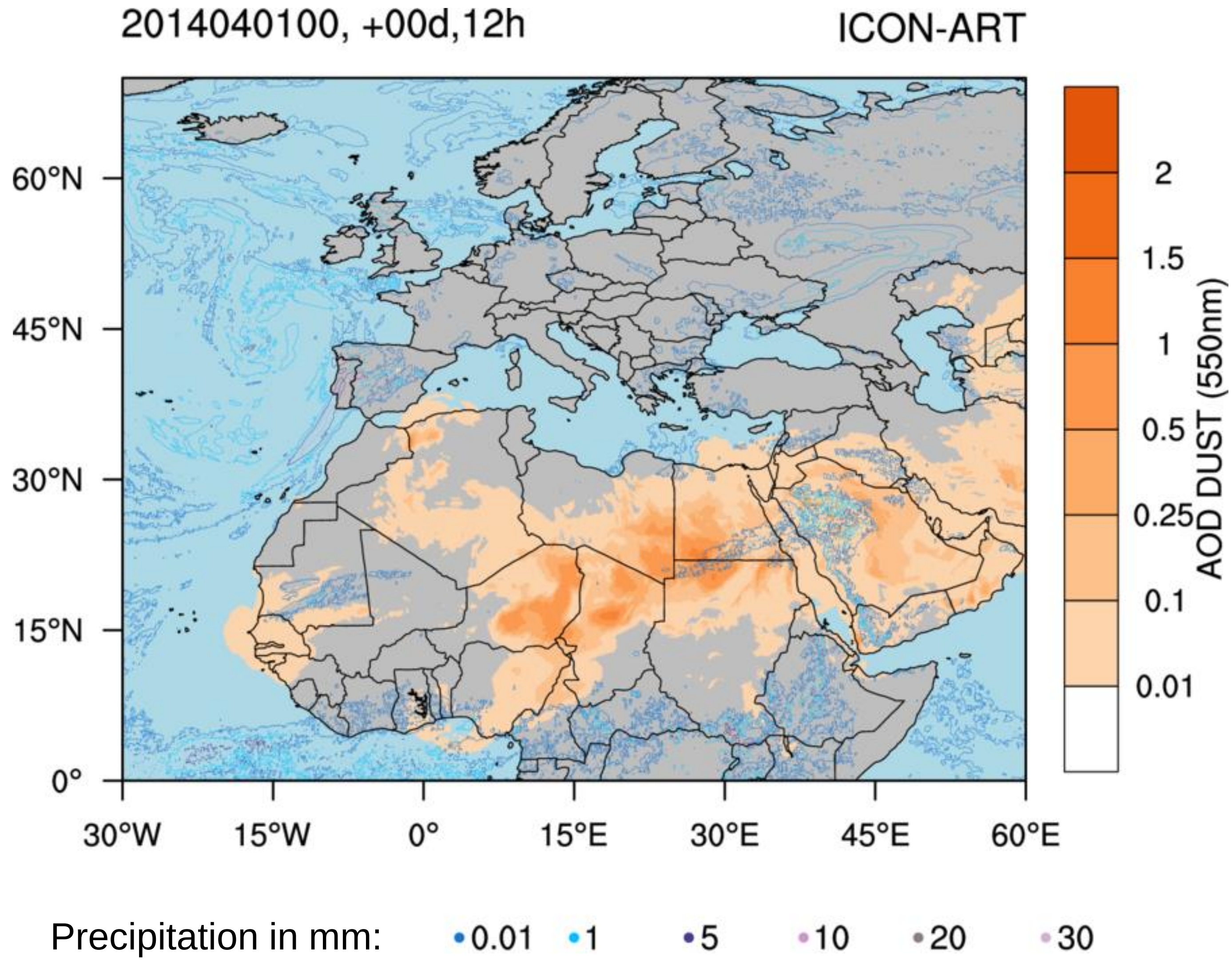

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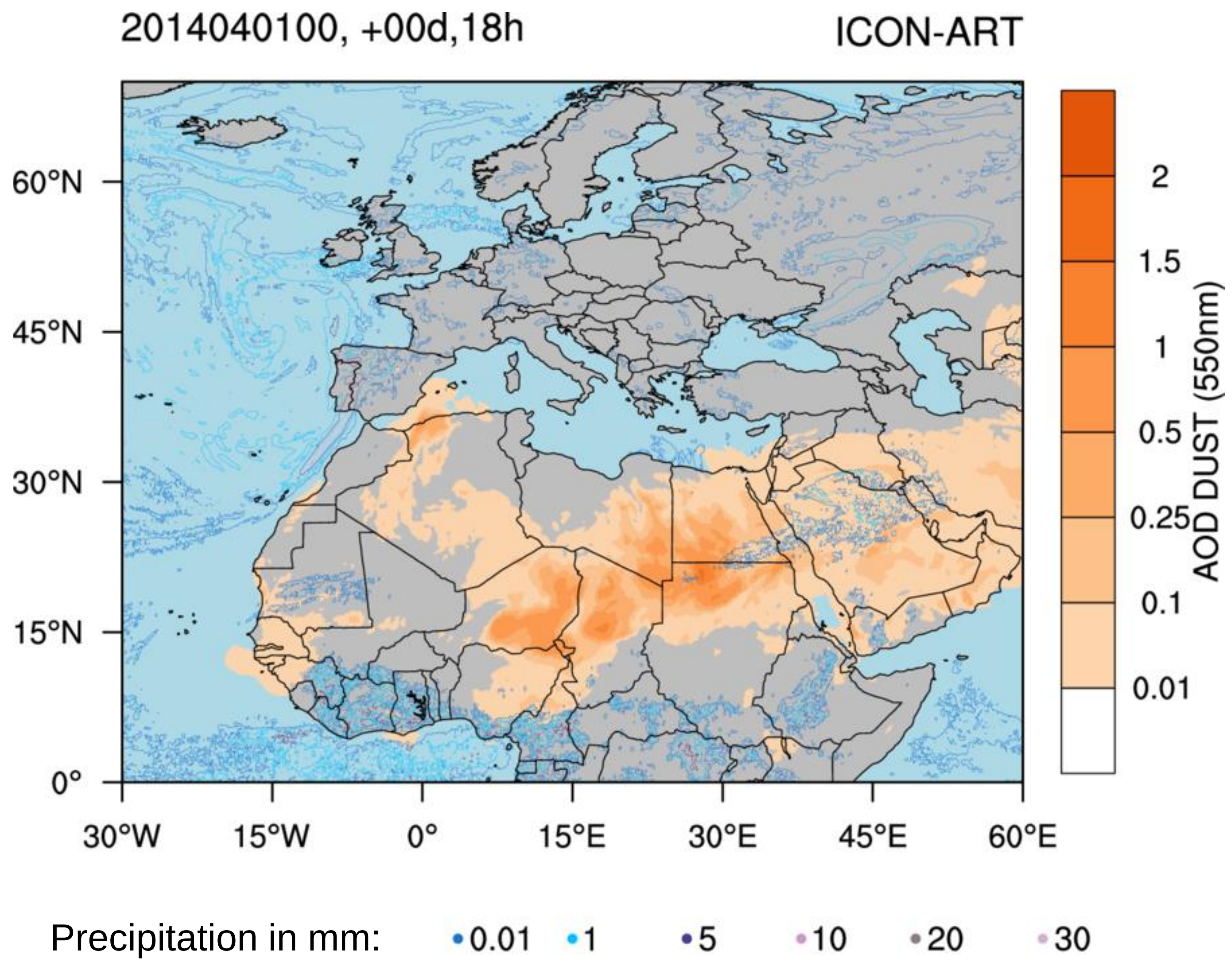

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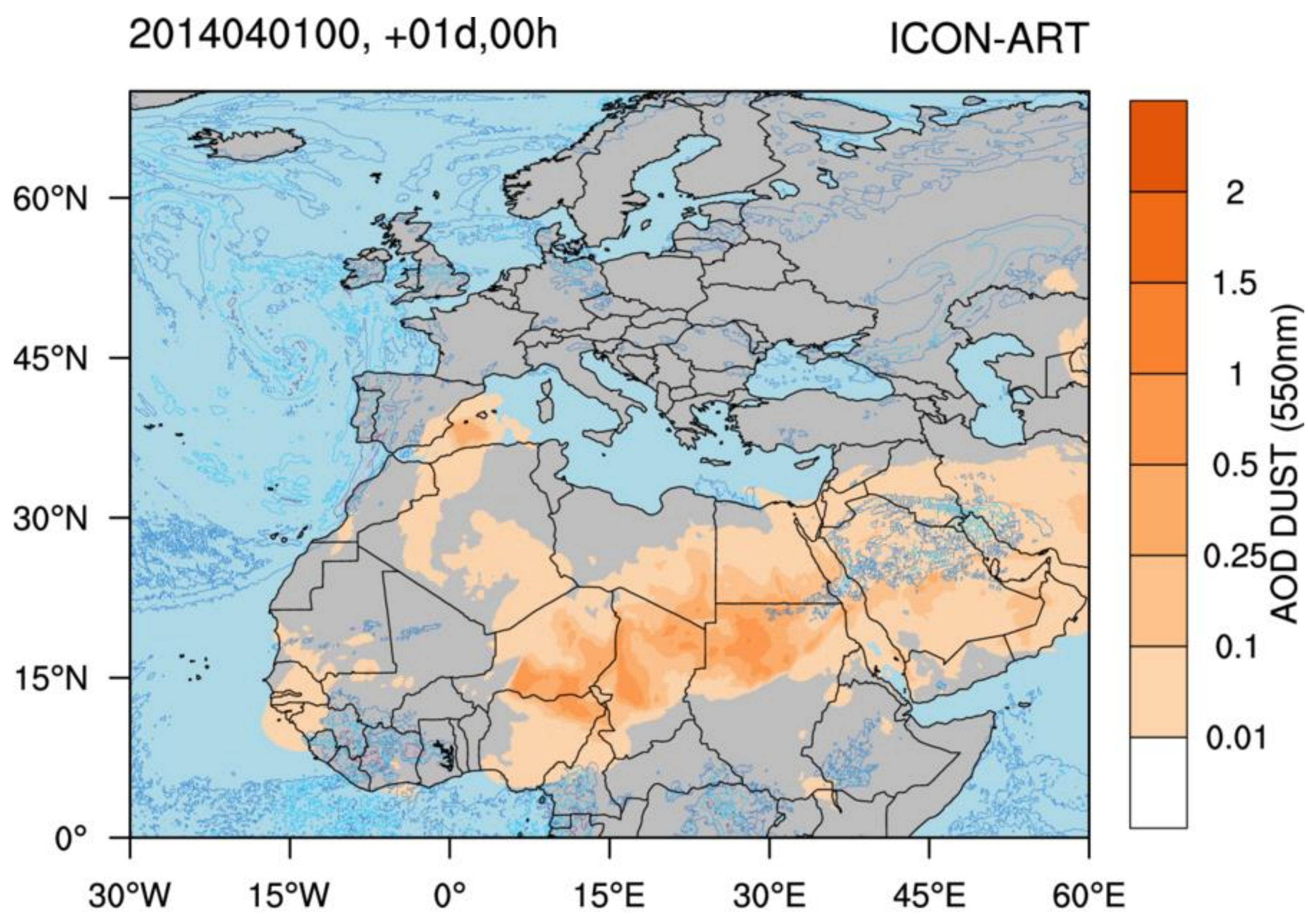

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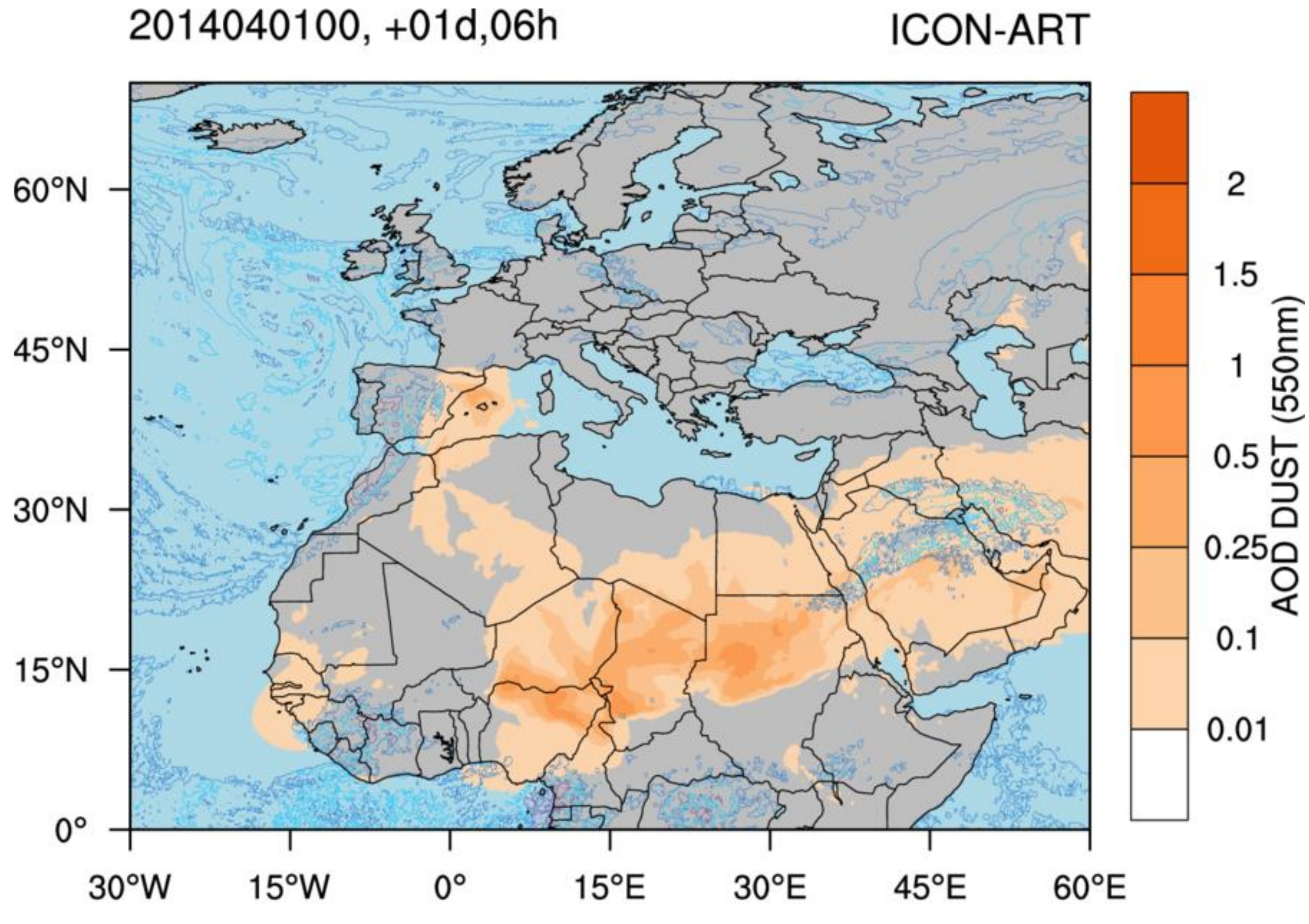

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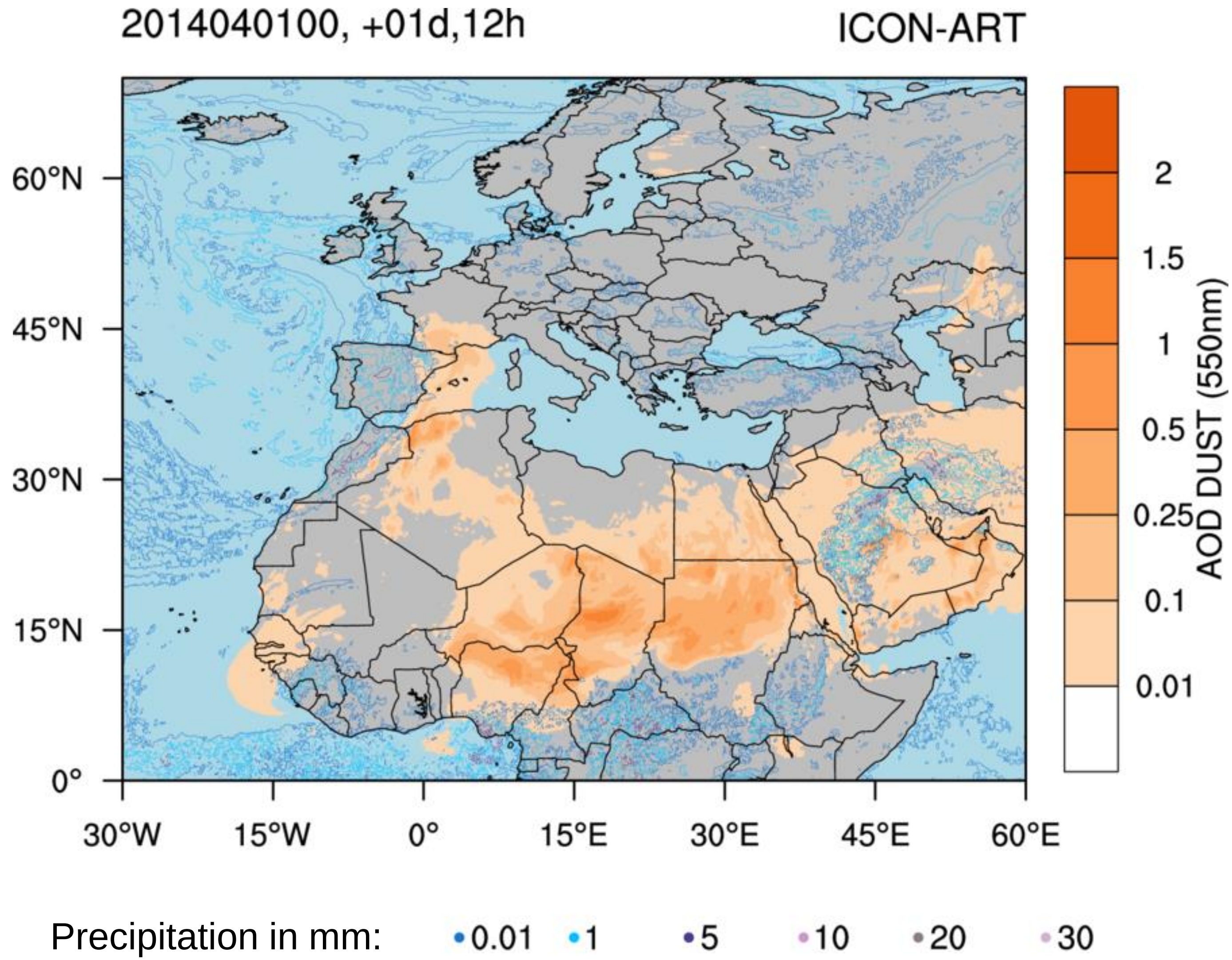

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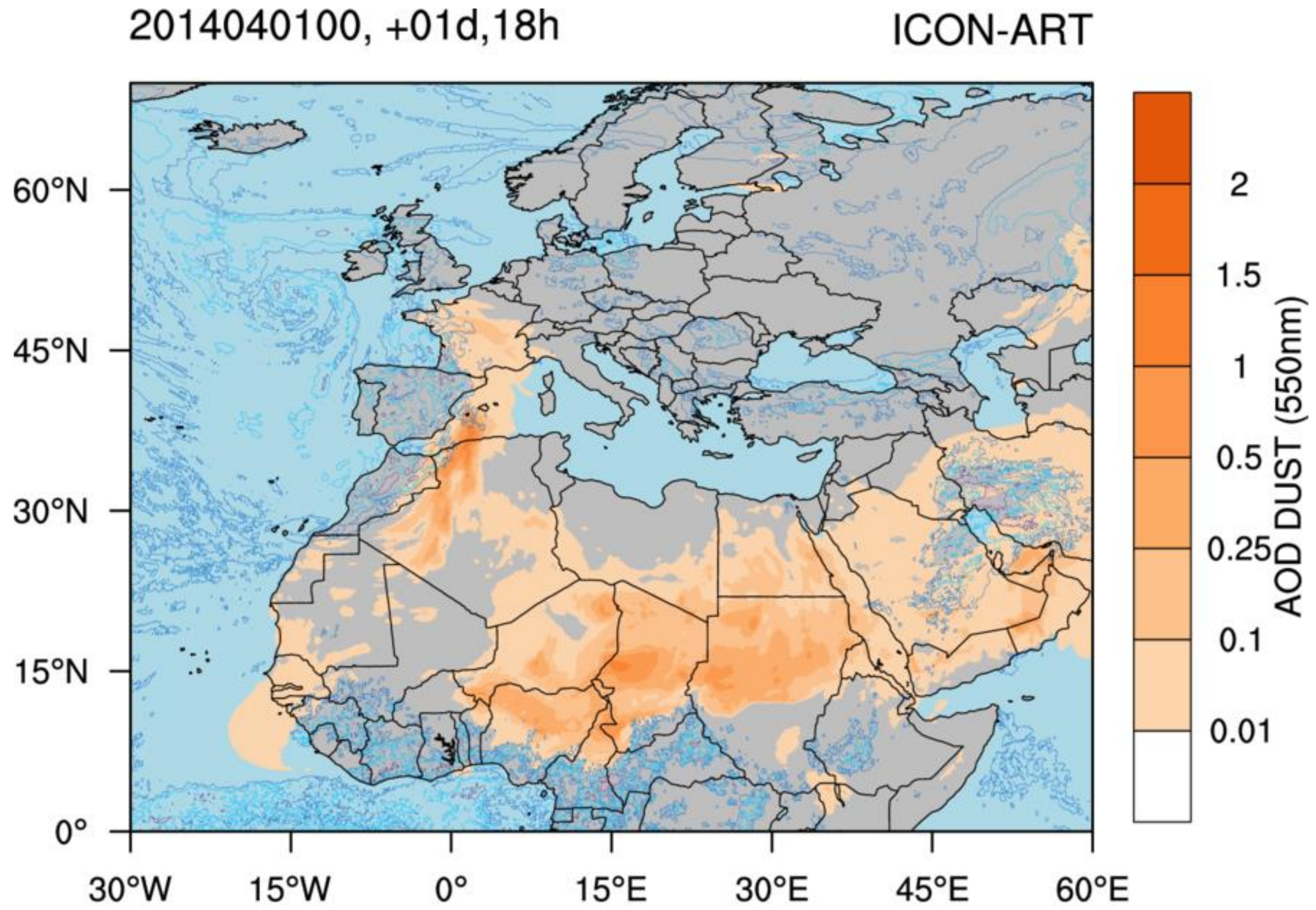

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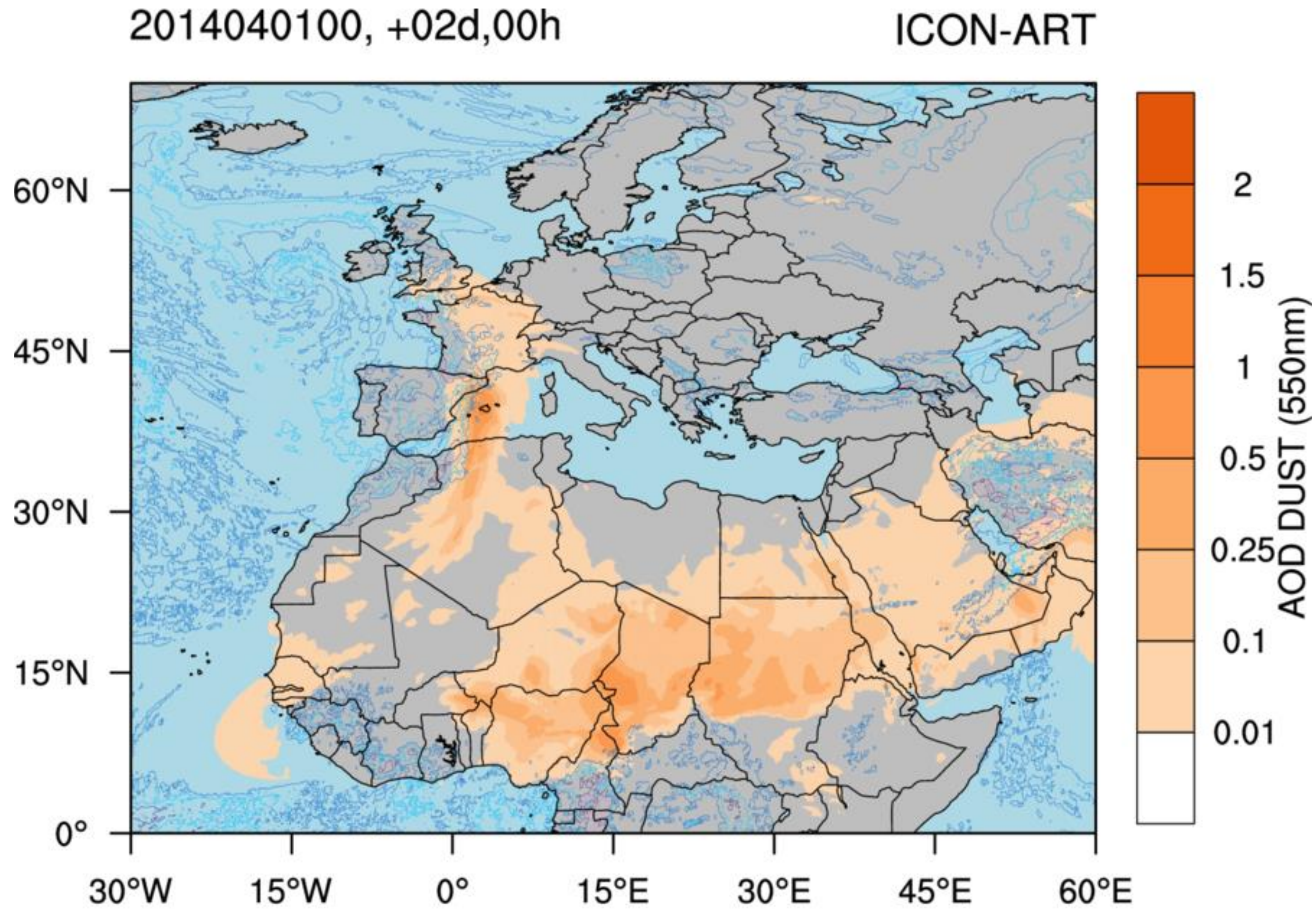

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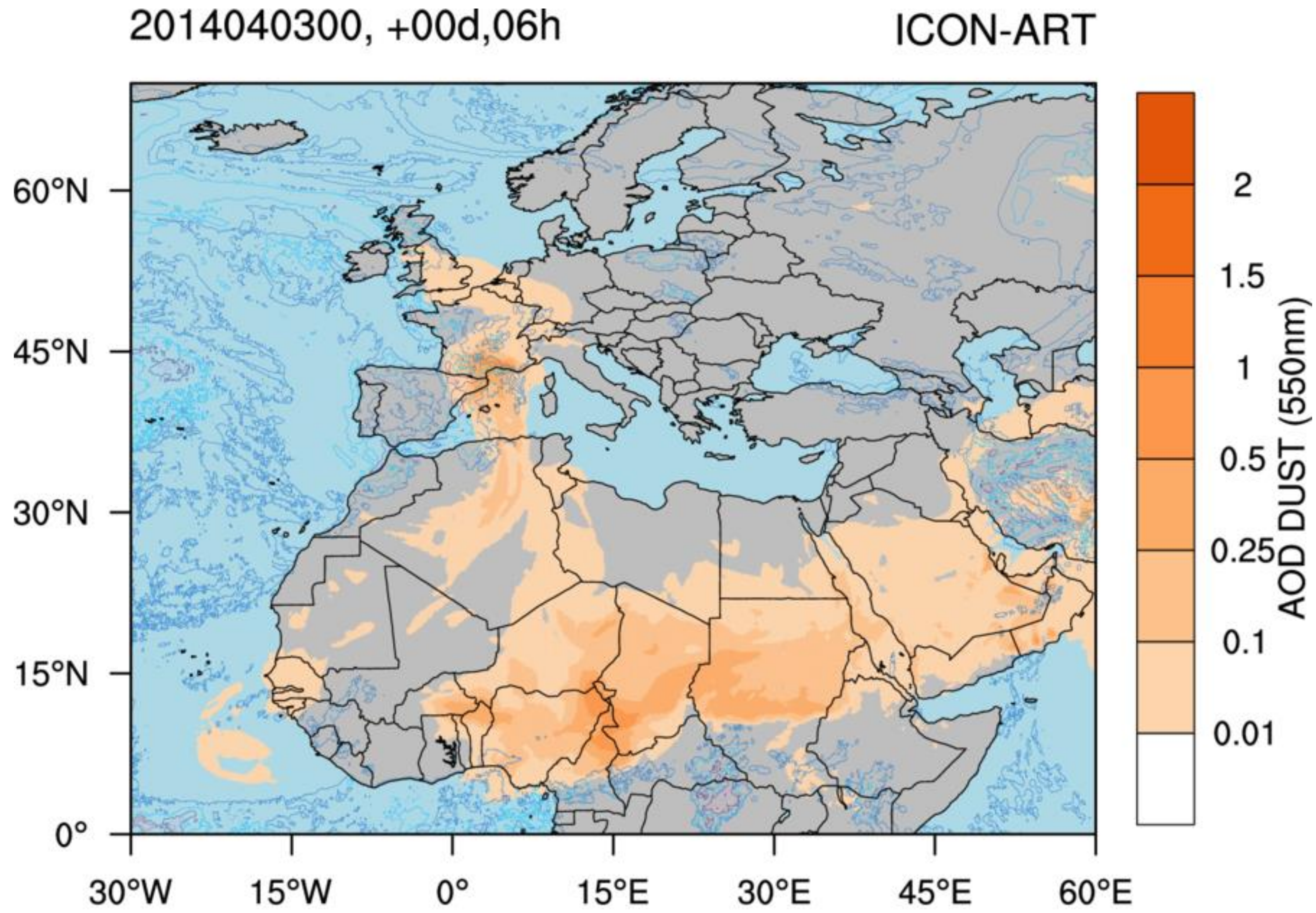

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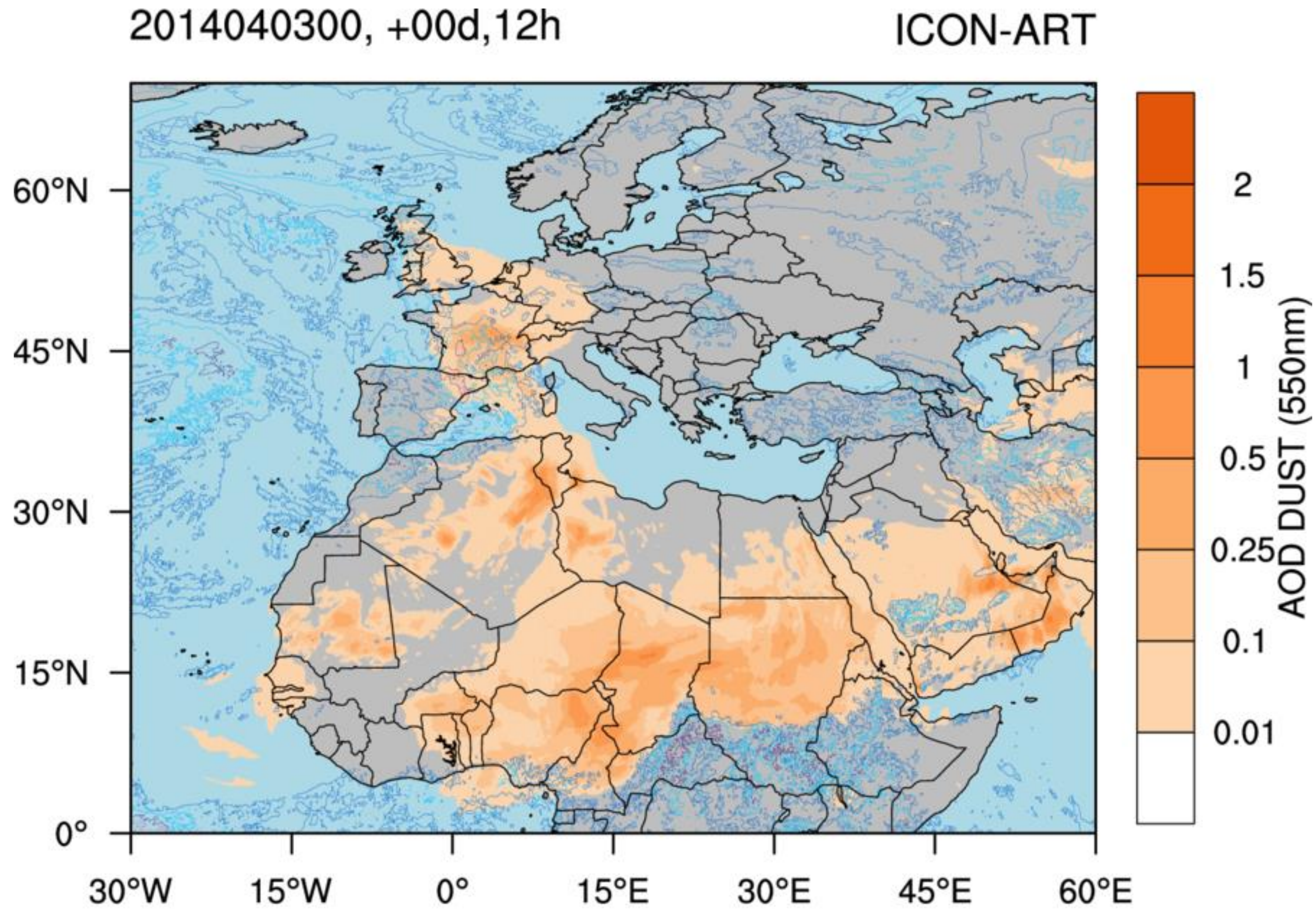

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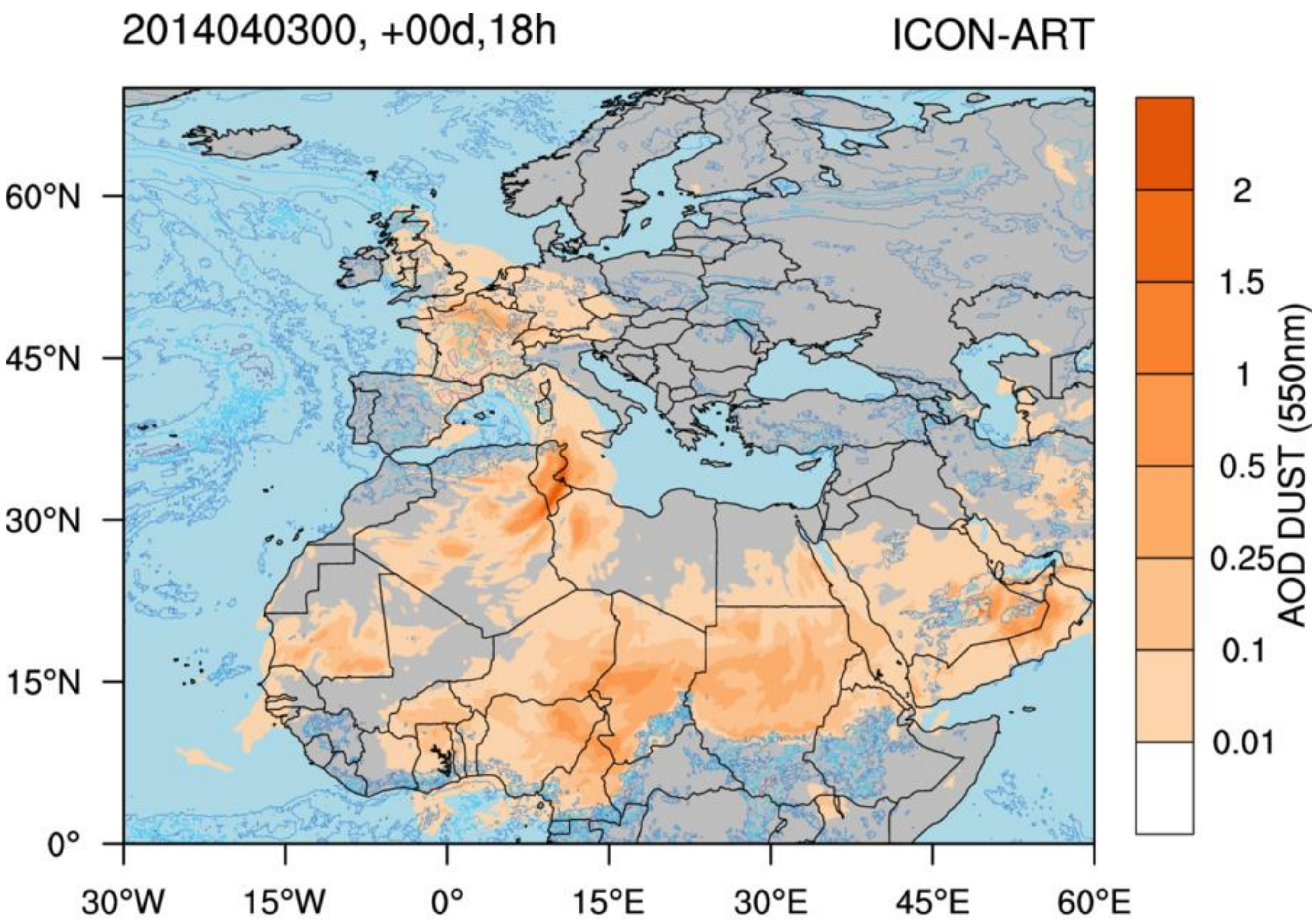

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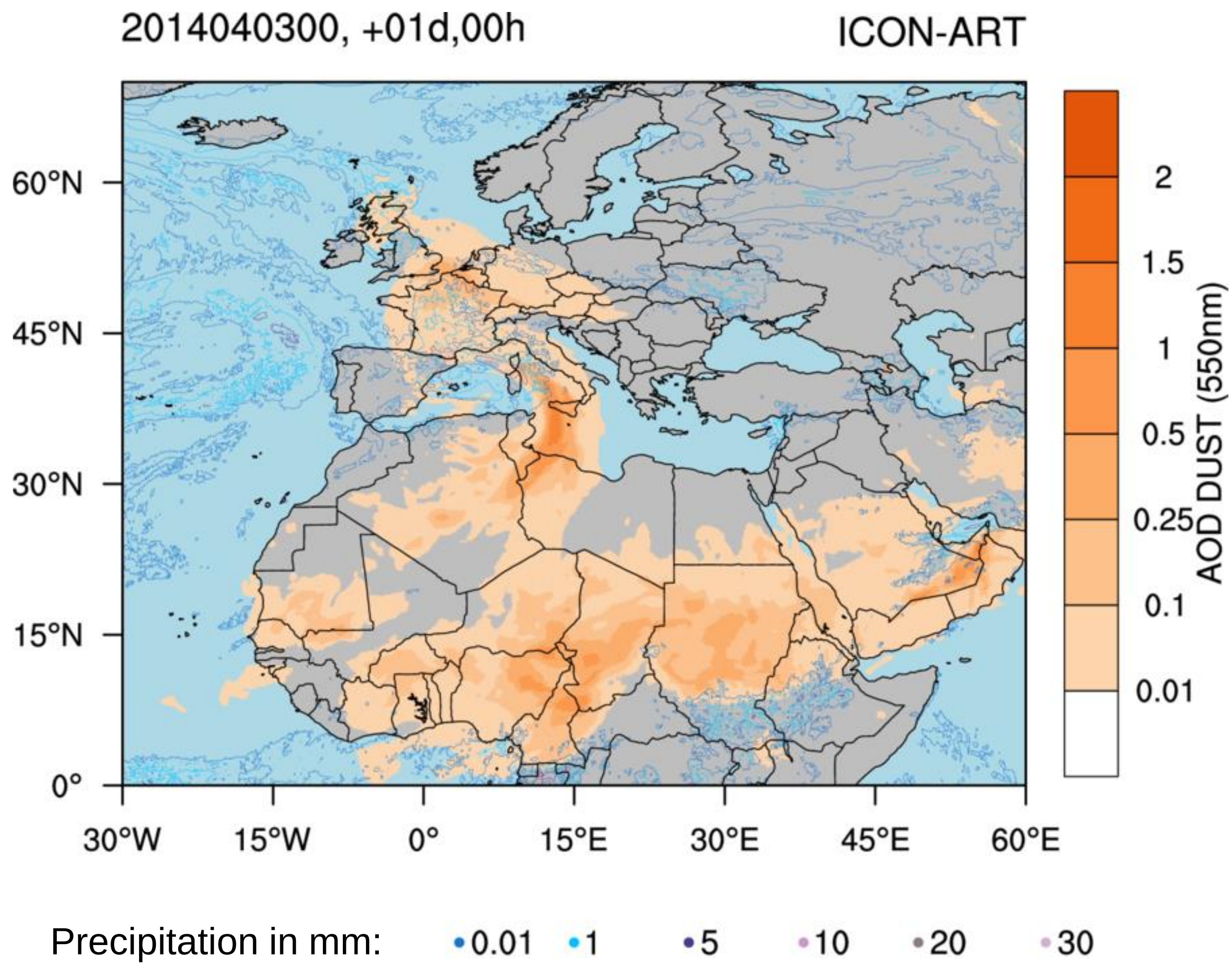

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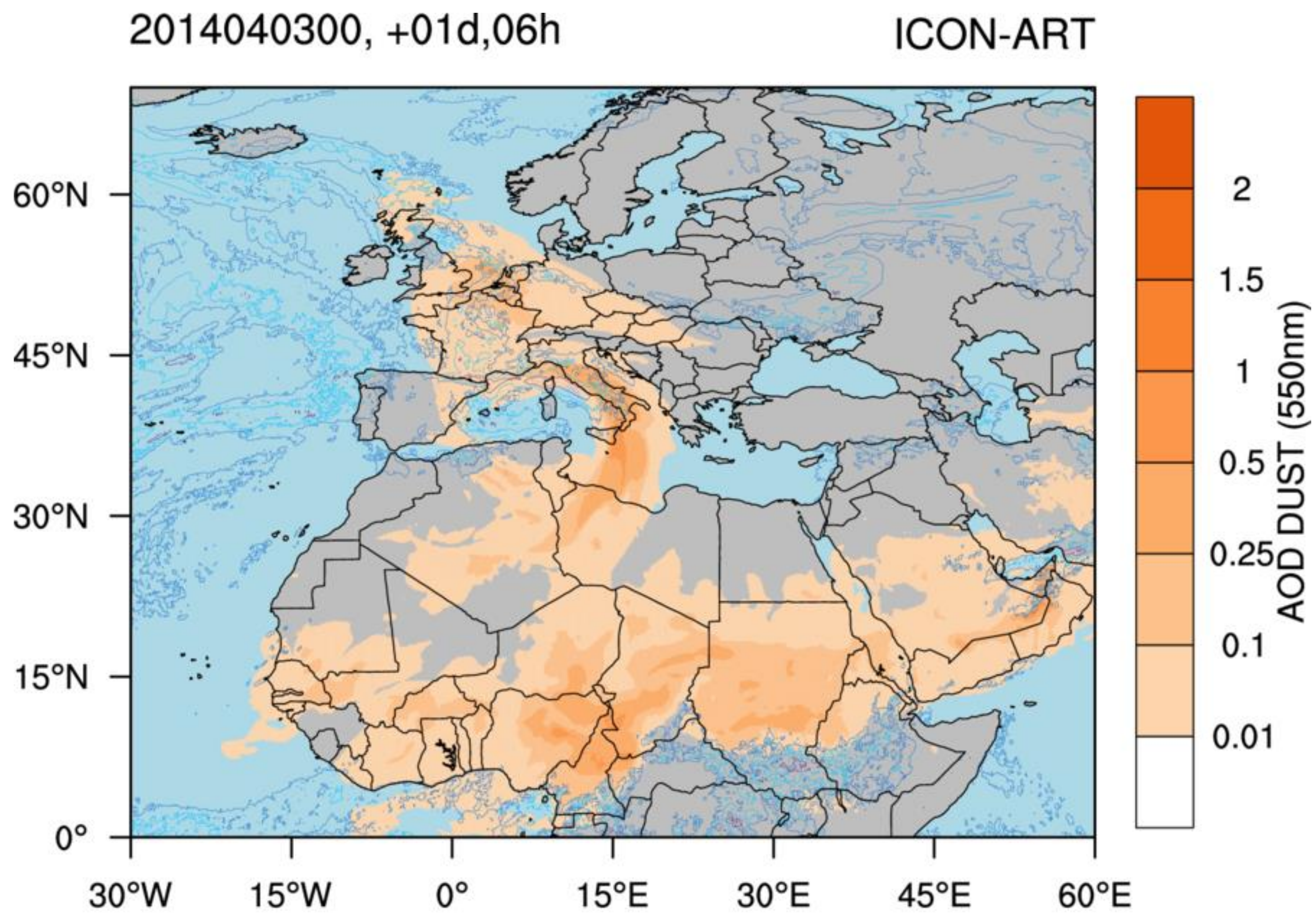

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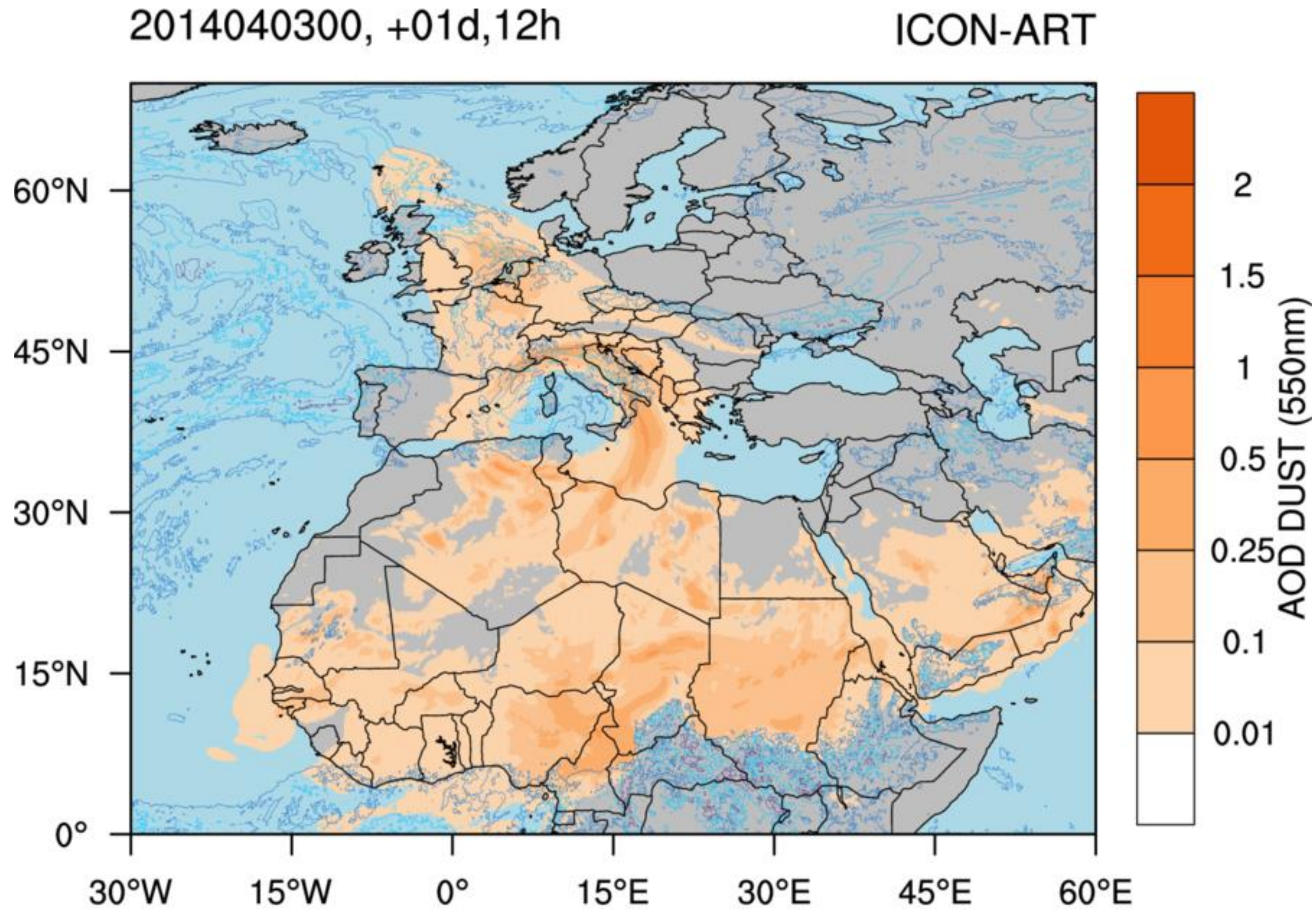

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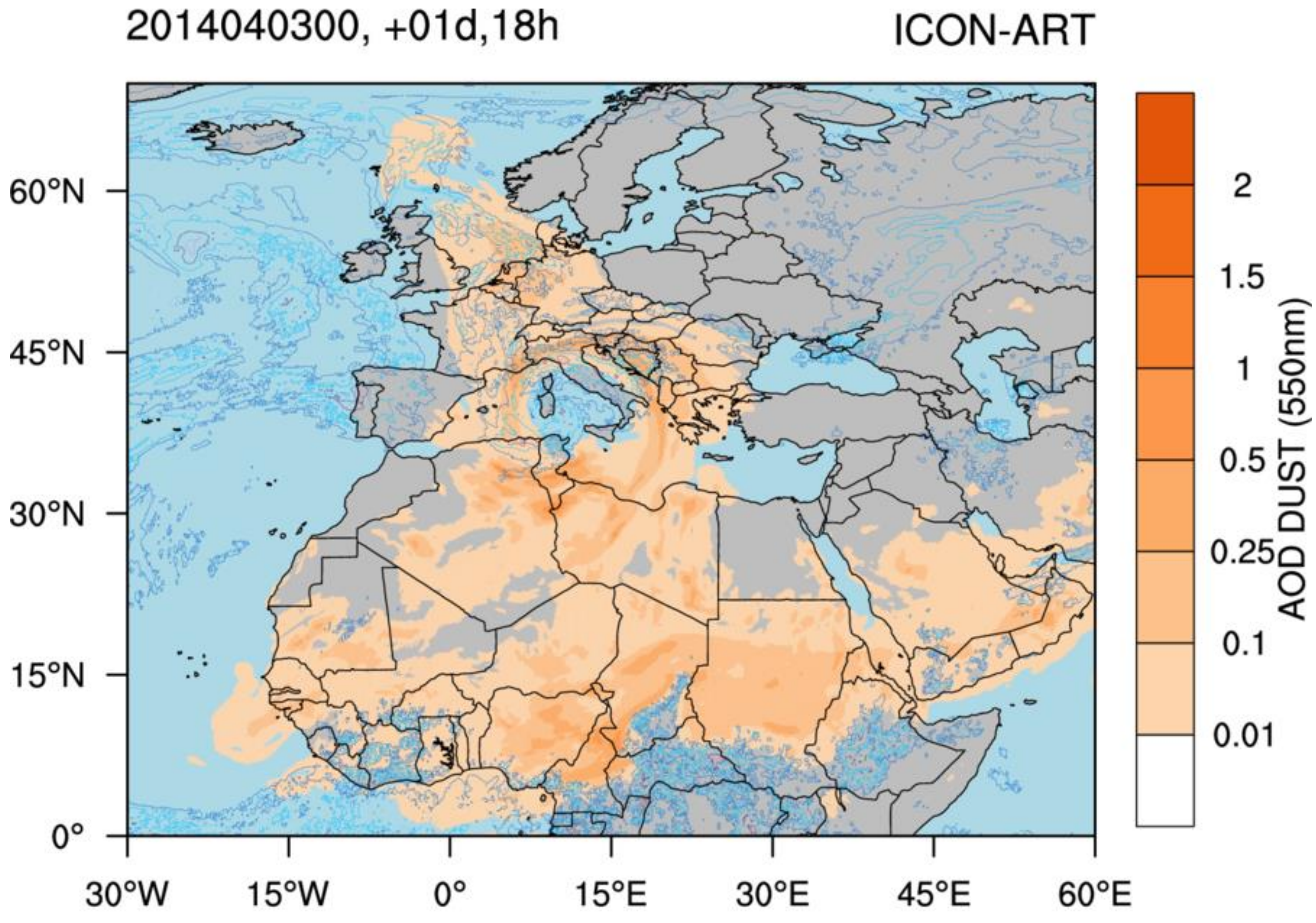

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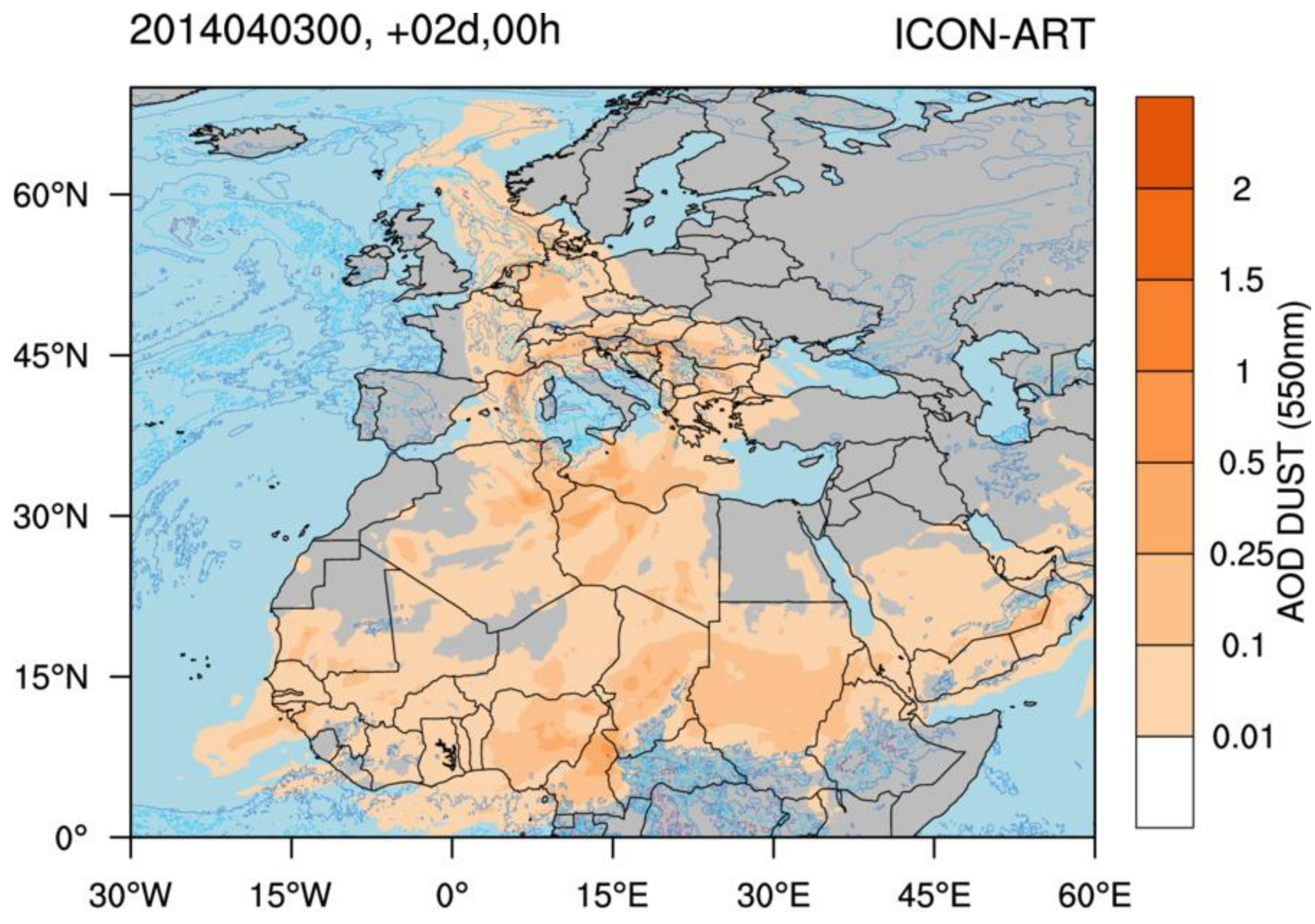

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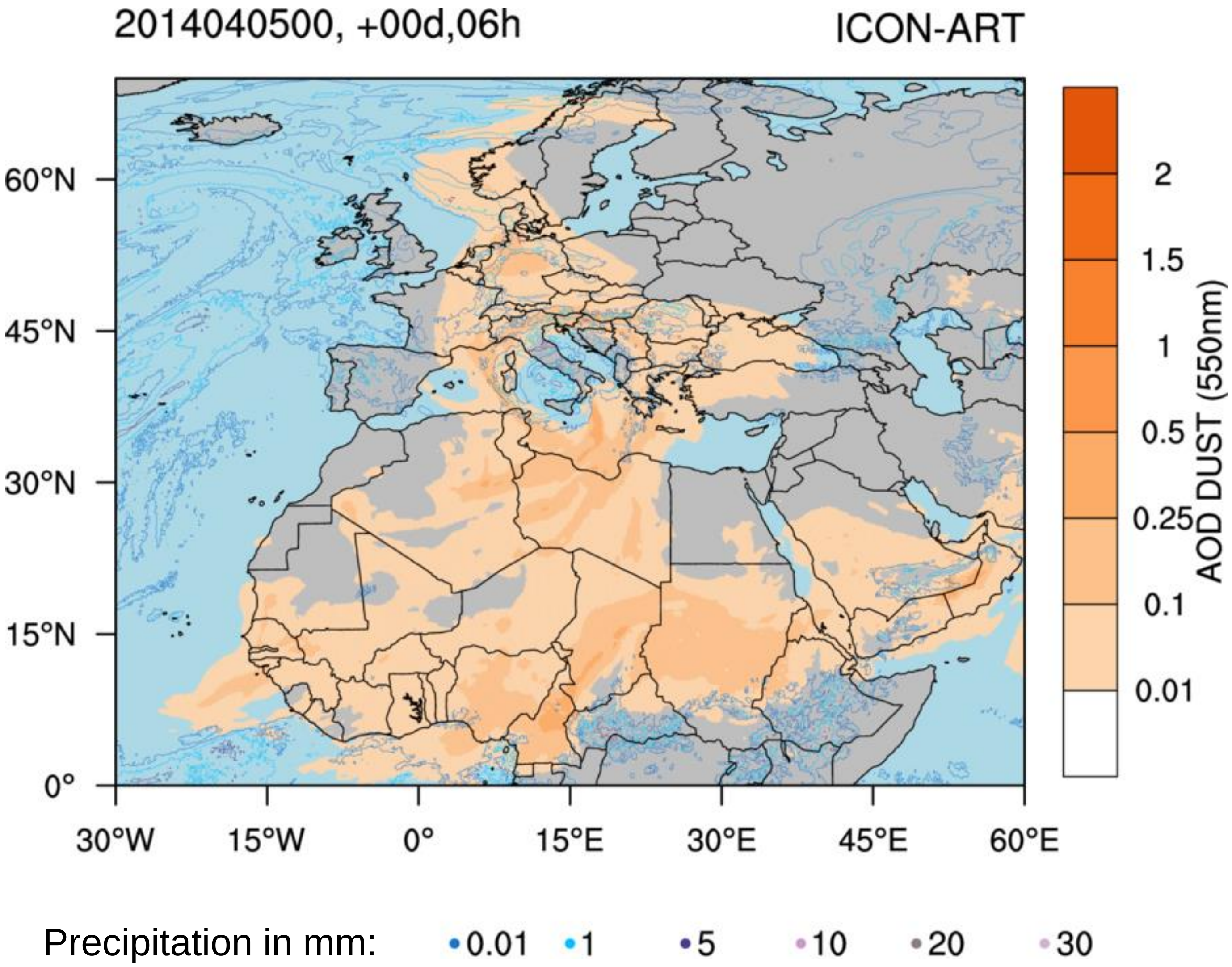

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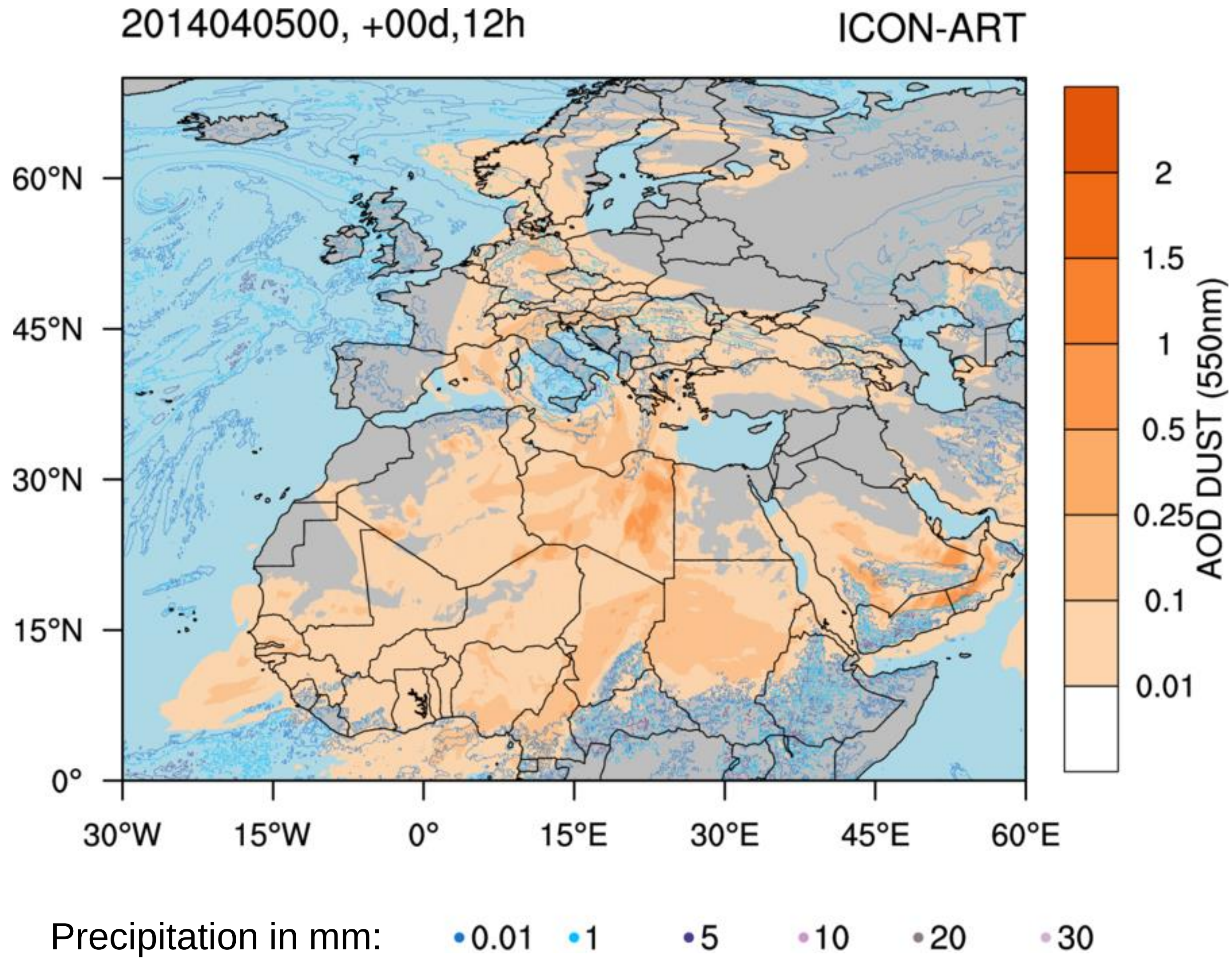

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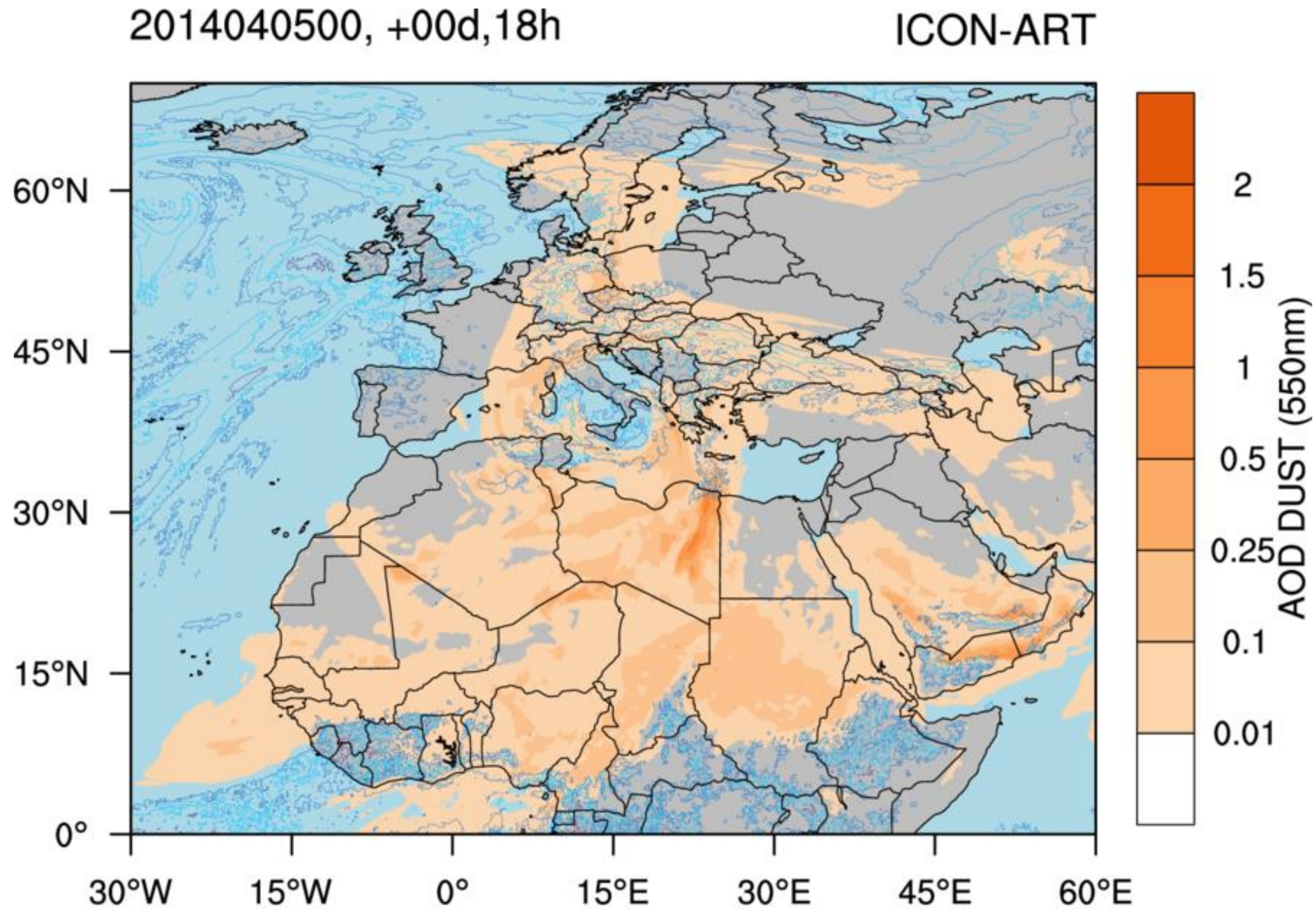

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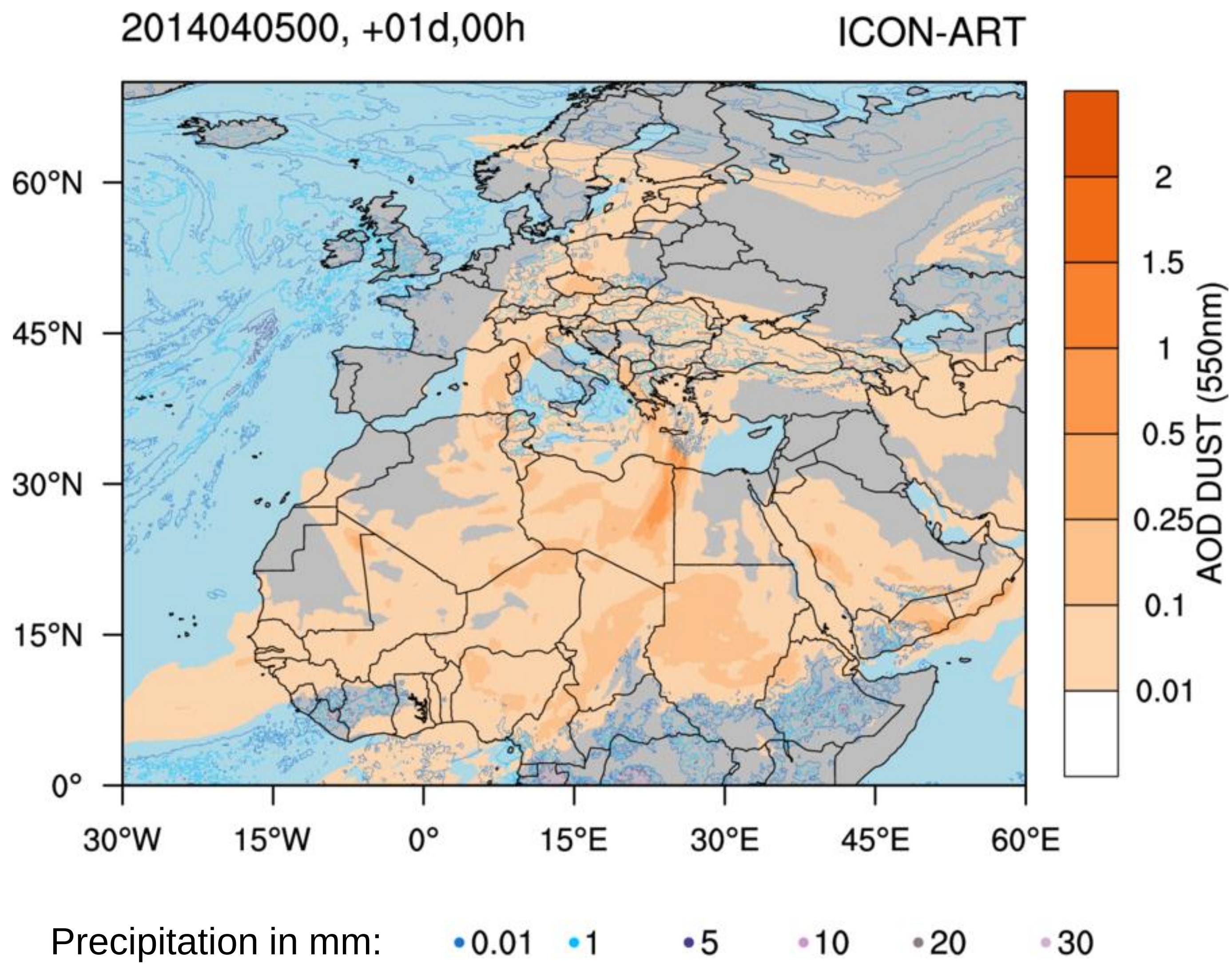

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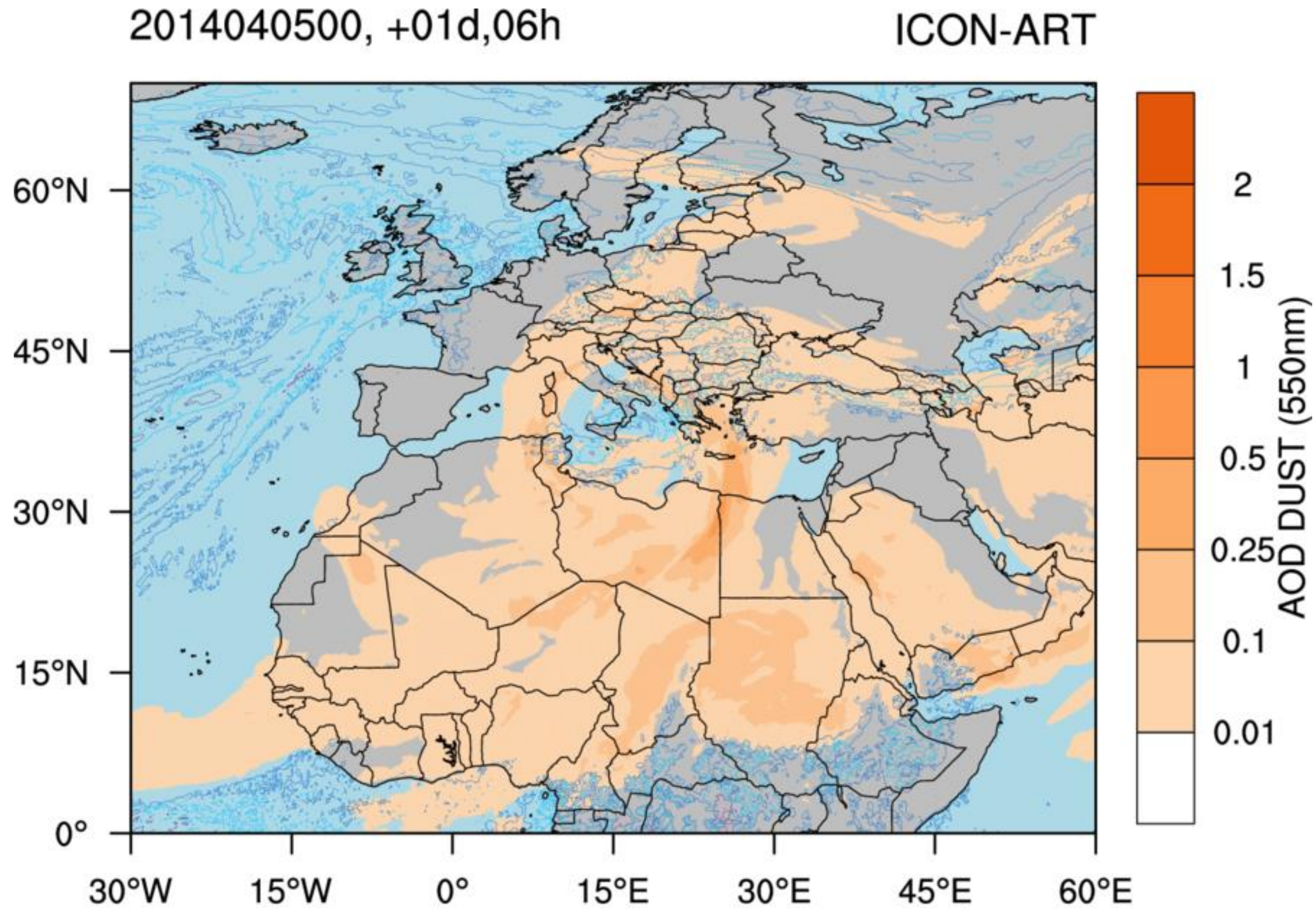

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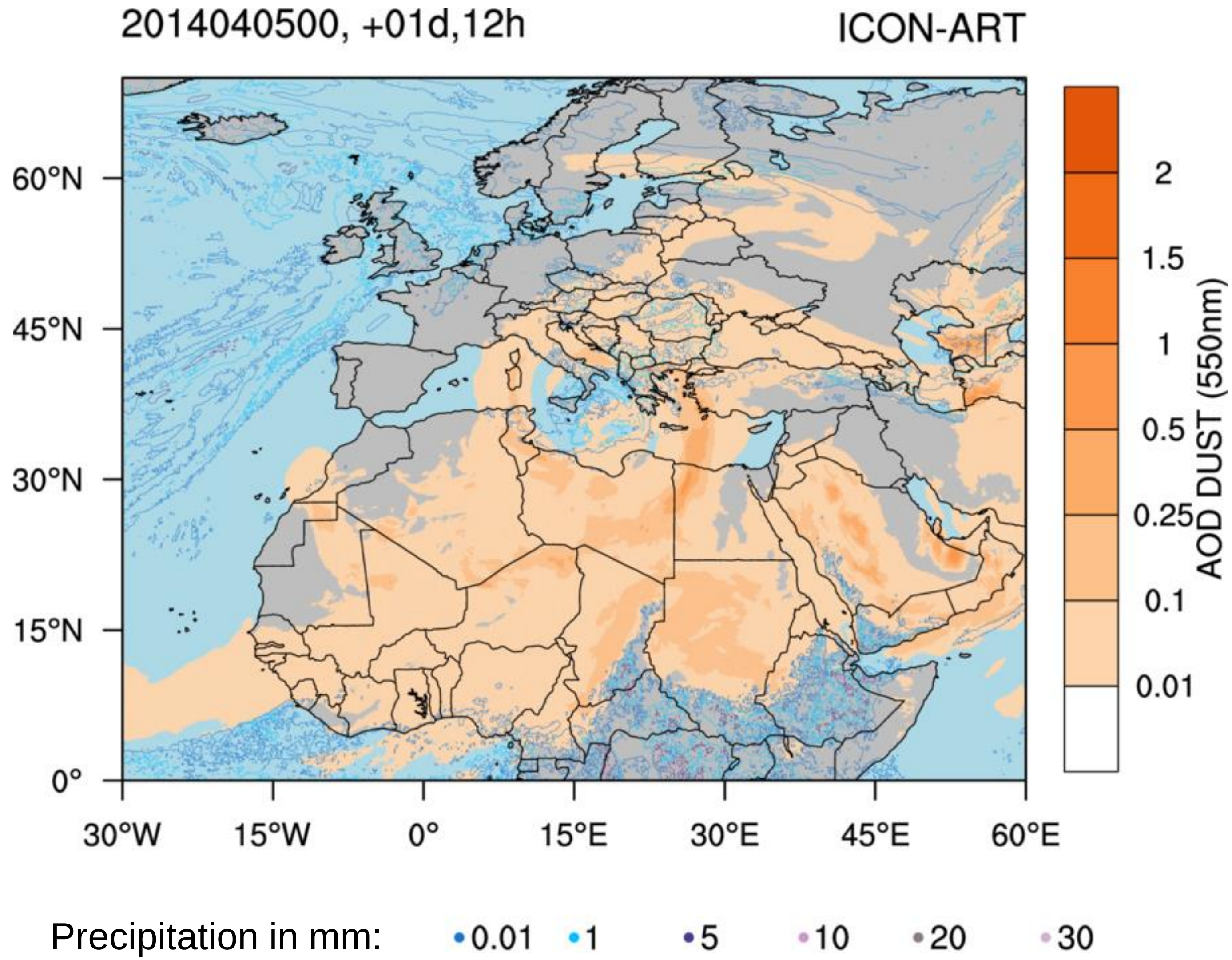

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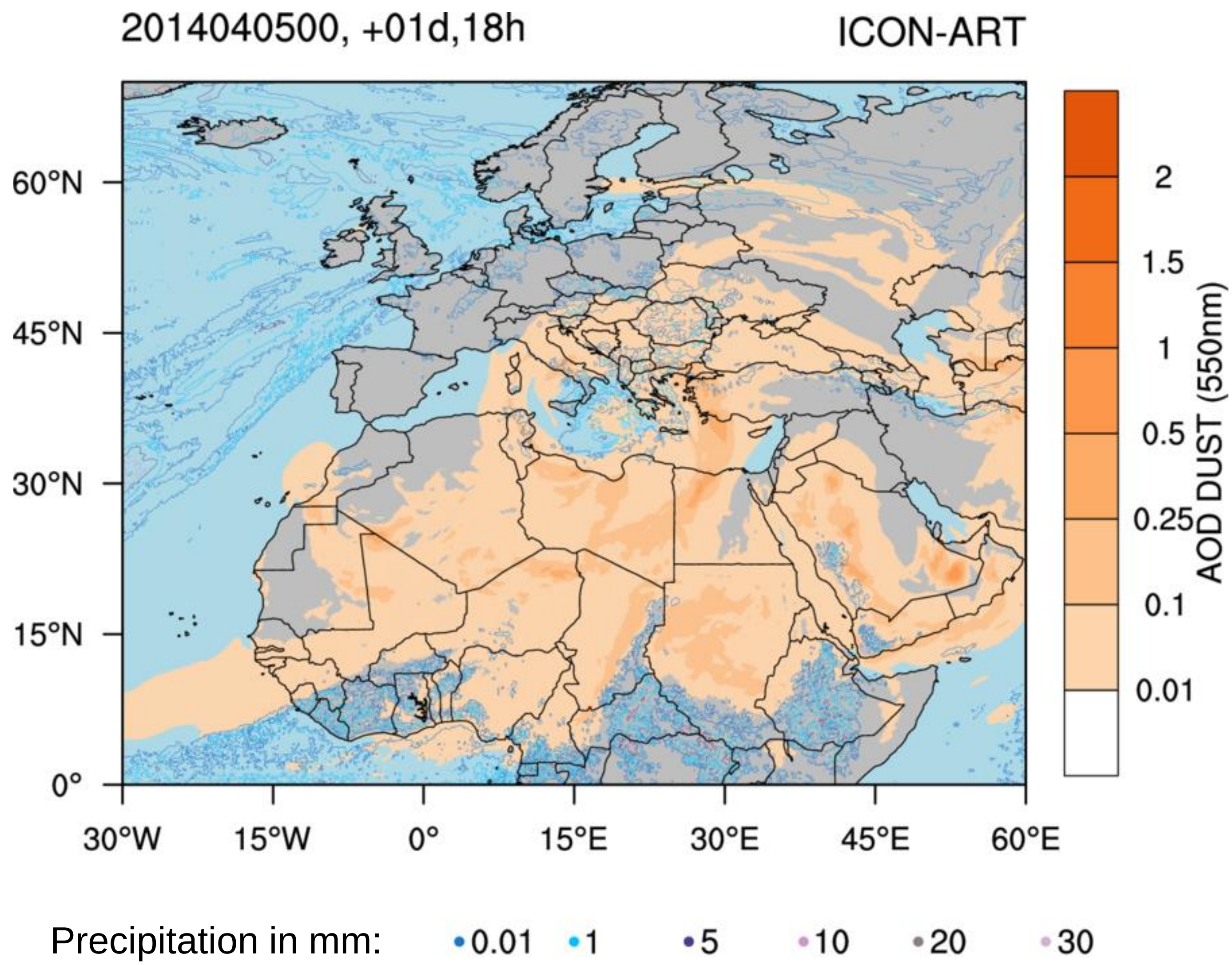
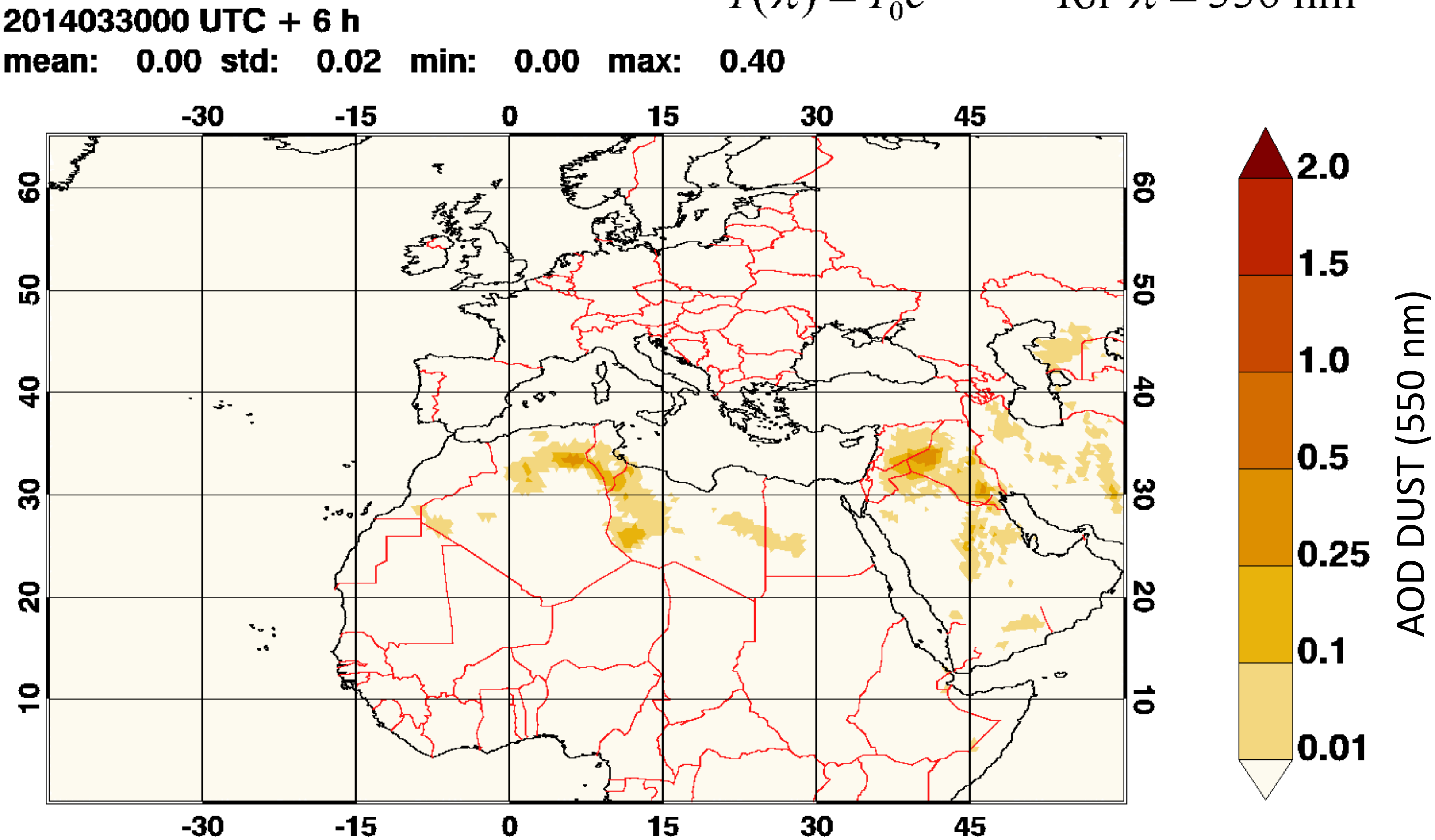


Resolution dependency

R2B06 (40 km)

$$I(\lambda) = I_0 e^{-\tau(\lambda)} \quad \text{for } \lambda = 550\text{ nm}$$



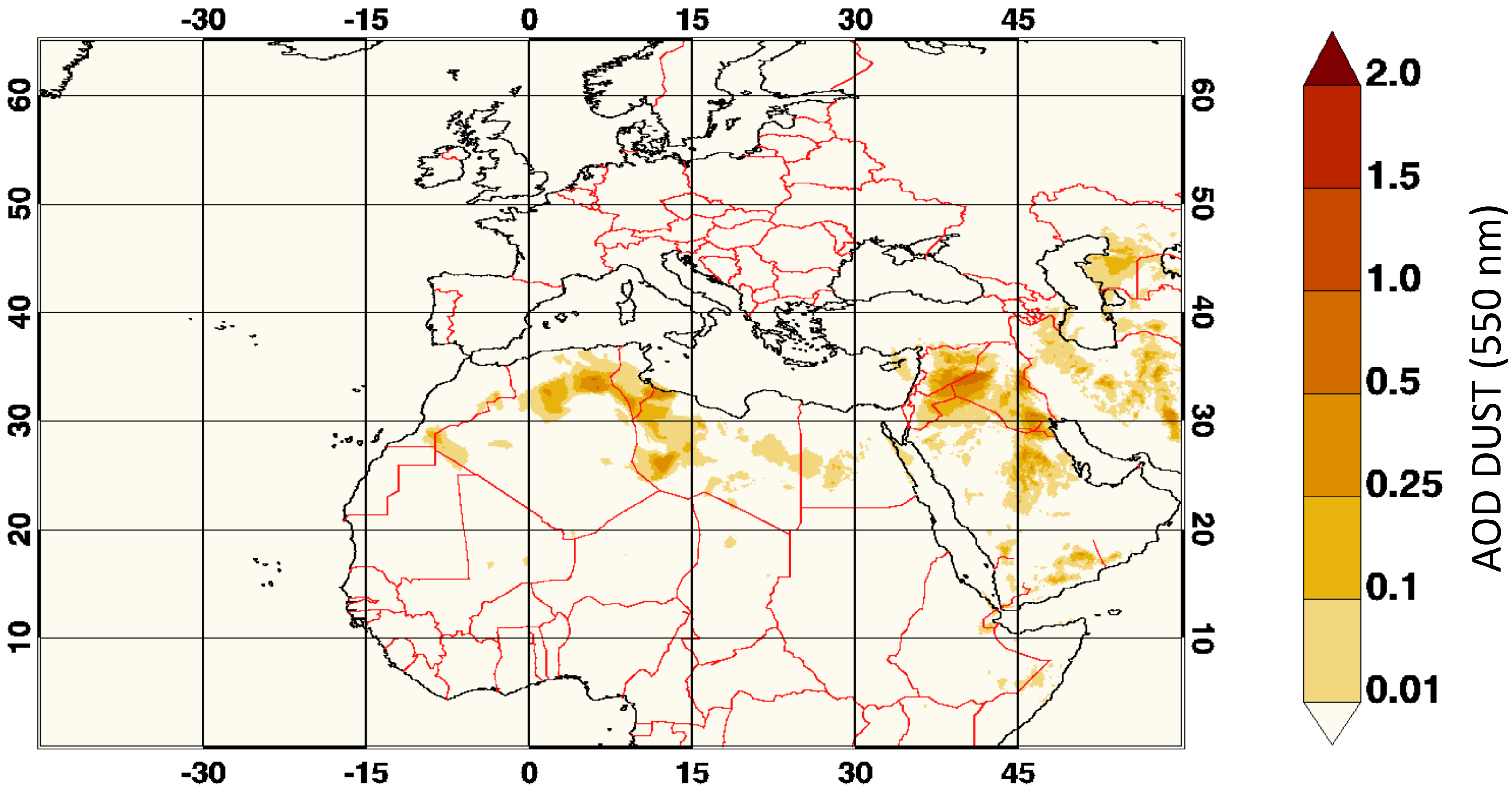
Resolution dependency

R3B07 (13 km)

2014033000 UTC + 6 h

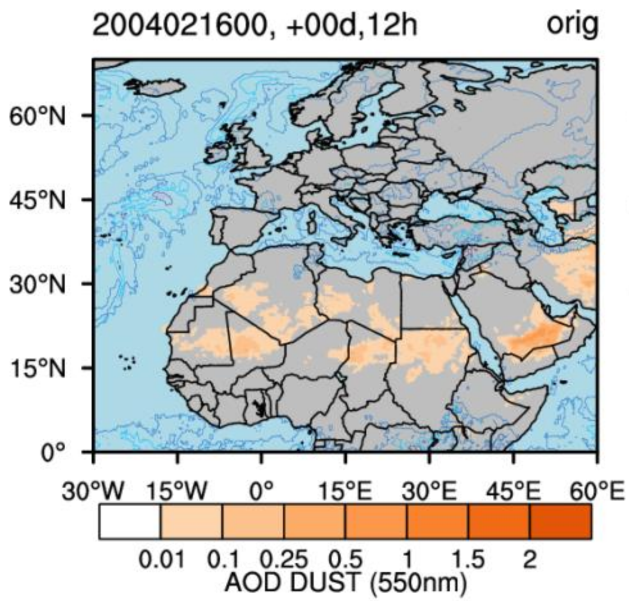
mean: 0.00 std: 0.03 min: 0.00 max: 0.91

$$I(\lambda) = I_0 e^{-\tau(\lambda)} \quad \text{for } \lambda = 550 \text{ nm}$$



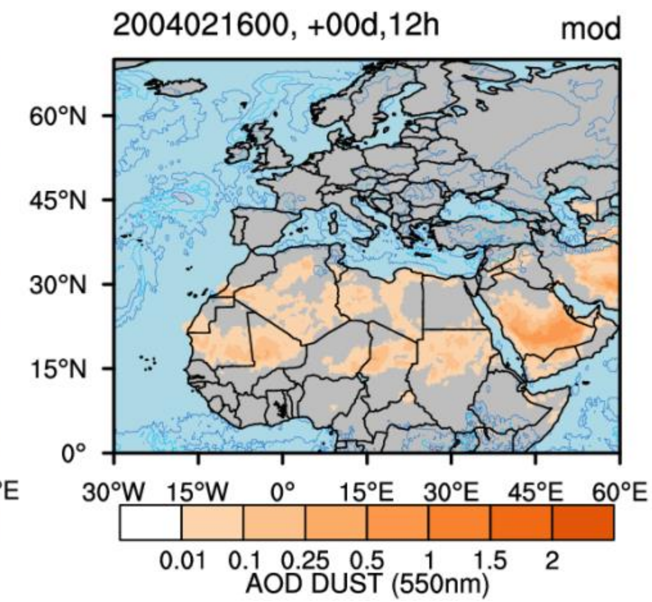
Soil-moisture dependency

Original

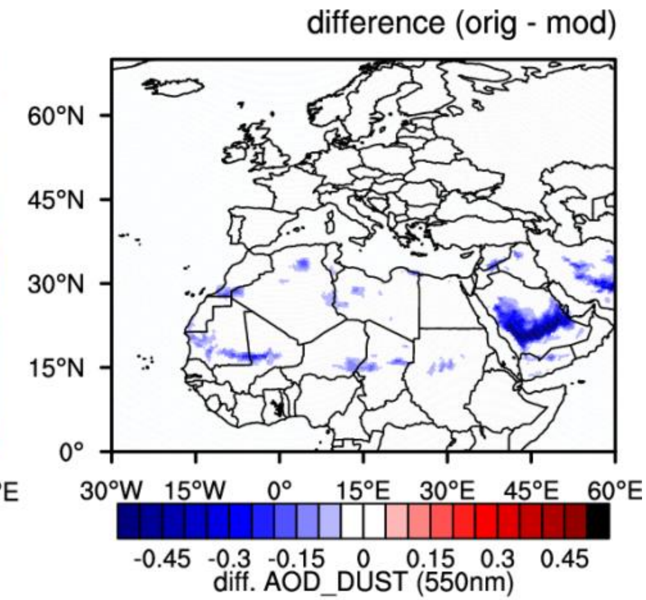


Very dry soil

(w_so *0.01 over N-Africa)



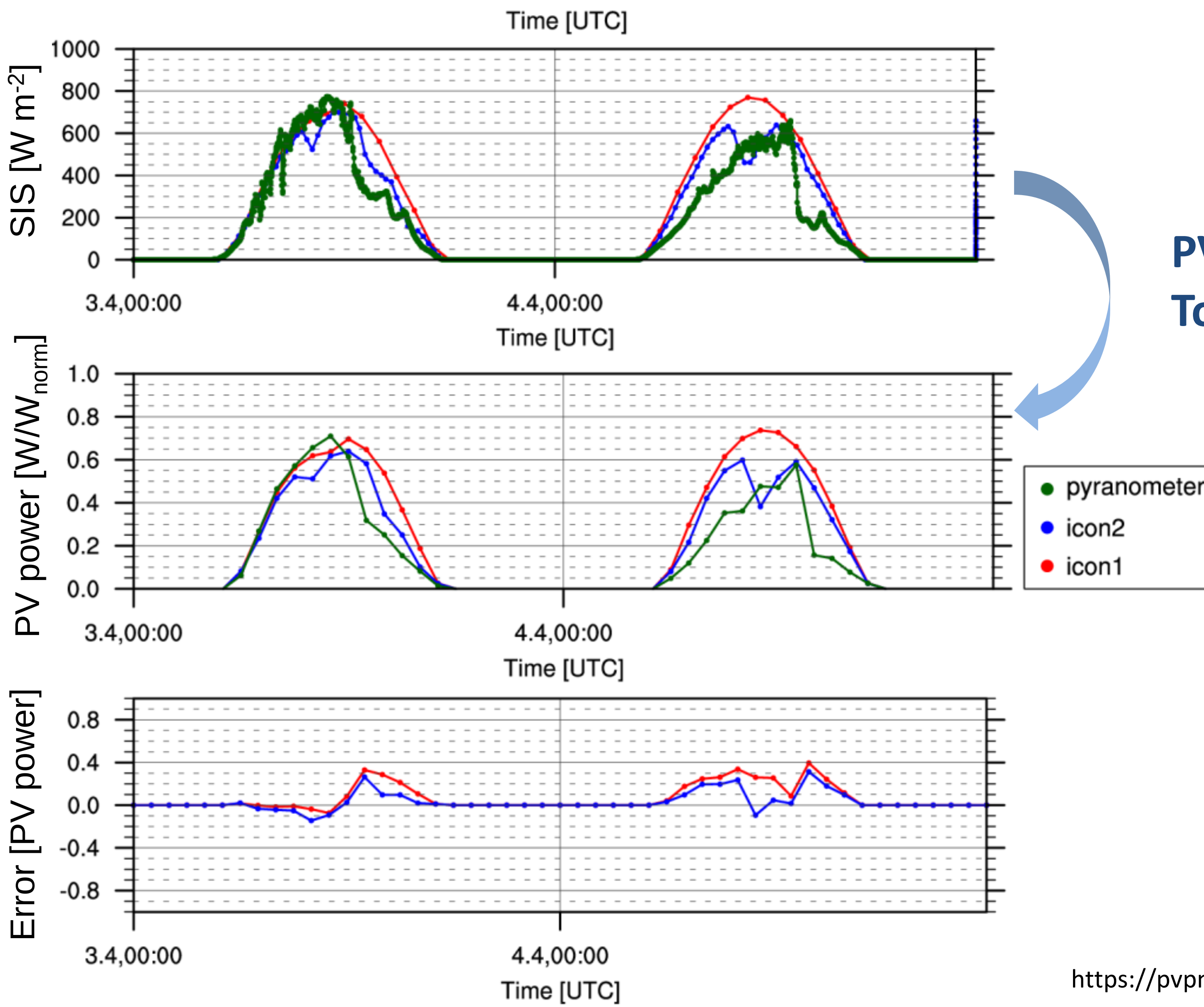
Difference



→ Total DUST [kg] in atmosphere after 12 h:

Original	W_SO *0,5	W_SO *0,01
$2{,}25 \cdot 10^9$	$3{,}71 \cdot 10^9$	$4{,}47 \cdot 10^9$
	+64%	+98%

Study 30.03.2014 – 06.04.2014



PV_LIB*)
Toolbox for Python

→ date, time
→ lat, lon
→ altitude
→ tilt, orientation
→ albedo
→ temperature
→ wind speed
→ diffuse radiation
→ global radiation

*) Andrews et. al. 2014,
https://pvpmc.sandia.gov/applications/pv_lib-toolbox/

Outlook ICON-ART development

Started

- → Emission (resolution, soil moisture)

Coming up

- → Washout
- → Aerosol optical properties

Towards a continuous application at DWD:

- → Now: start from dust free atmosphere
- → Near Future: daily global ICON-ART runs
- → Future: Possibly adaptive ICON-ART nest with higher resolution in case of Saharan dust outbreak

Thank You!

Photograph by Frans Lanting, National Geographic

Literature

➔ Andrews, R. W., Stein, J. S., Hansen, C., and Riley, D.: Introduction to the Open Source PV_LIB for Python Photovoltaic System ModellingPackage, in 40th IEEE Photovoltaic Specialist Conference, 2014.

➔ Flentje, H., Briel, B., Beck, C., Collaud Coen, M., Fricke, M.,Cyrys, J., Gu, J., Pitz, M., and Thomas, W.: Identification and monitoring of Saharan dust: An inventory representativefor south Germany since 1997, Atmospheric Environment, 109,87–96, doi:http://dx.doi.org/10.1016/j.atmosenv.2015.02.023

➔ Rieger, D., Bangert, M., BischoffGauss, 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.

➔ Versick: Vergleich verschiedener Messmethoden für Strahlungskenngrößen des atmosphärischen Aerosols. Diplomarbeit, Universität Karslruhe (TH), http://www.imktro.kit.edu/download/Versick_Diplomarbeit.pdf, 2006. 136.

➔ Zängl, G., Reinert, D., Rípodas, P., and Baldauf, M.: The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M:Description of the non-hydrostatic dynamical core, Q. J. Roy. Meteor. Soc., 141, 563–579, doi:10.1002/qj.2378, 2015.