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Aerosol forecast and research with ICON-ART

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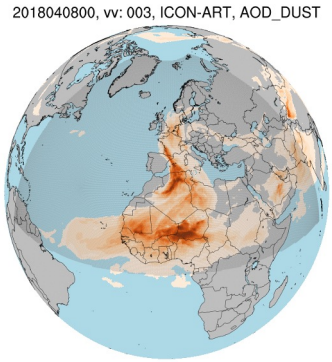

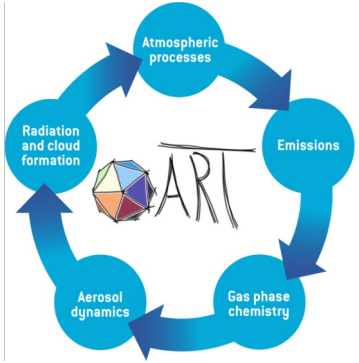

What should a “weather service” provide

- **in the 70’s** → day-ahead weather forecast

- **today** → hours to months weather, environment and climate forecast

ICON-ART

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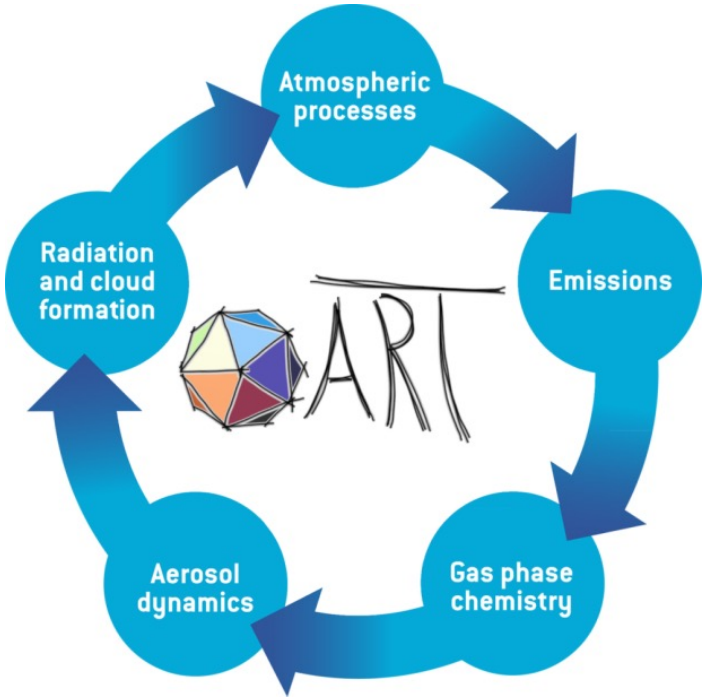


ICOsahedral **N**onhydrostatic

Zängl et al. (2015), Giorgetta et al. (2018)

Aerosol and **R**eactive **T**race gases

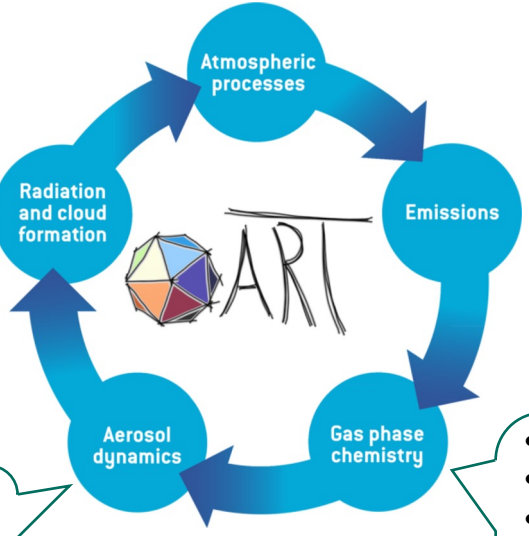
Rieger et al. (2015), Weimer et al. (2017)

General features:

- Online fully-coupled for LEM, NWP and climate simulations
- Adaptable to global, nested and limited area configurations
- Fully modular and interoperable
- Scalable and flexible tracer structure, chemistry and aerosol dynamics

ICON-ART : main features

- Optics of all natural aerosols
- Optics of internally mixed aerosols
- Coupling with radiation (full and reduced grid)
- Coupling with dynamics
- Coupling with 2mom scheme
- ML-based optics
- Dusty-cirrus



- All source/tracer types
- All natural aerosols
- Biomass-burning plumes
- Volcanic plumes
- Online emission module
- Fire source dynamics

- Modal treatment
- Internally- and externally mixed
- AERODYN
- Aqueous chemistry

- Lifetime based
- Linearized schemes (LINOZ, N_2O-NOy)
- Simplified OH chemistry
- "Complex (use-defined)" chemistry based on MECCA e.g. MOZART
- Case-specific mechanisms
- ML-based chemistry

ICON-ART in forecast

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- Radionuclides (emergency)
- Volcanic eruptions (emergency)
- Vegetation fires (emergency, operational global and ICON-D2)
- Release of toxic chemical substances (emergency)
- Sea salt (global and ICON-D2)
- Pollen (regional, operational, also at MeteoSwiss)
- CH4, CO2 (passive) - "Integrated Greenhouse Gas Monitoring System“
- Mineral dust (global and ICON-D2, operational)

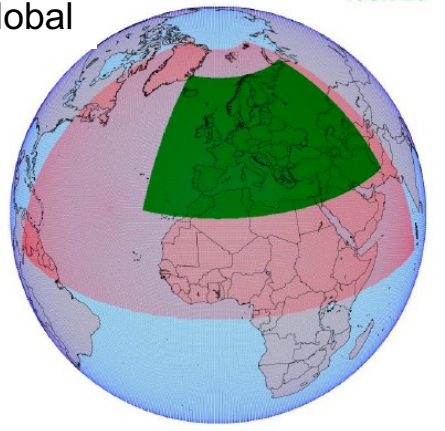
Check our website for more info: https://www.icon-art.kit.edu

Dust forecast system

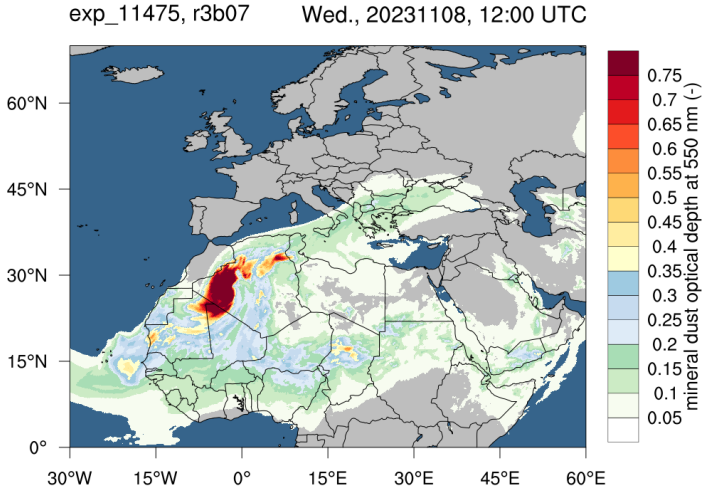
since December 2017: daily. 00, 12 UTC forecast until +180h (global), 120h (nest)

26 km global

13 km Nest



Today‘s forecast



Check our dust dashboard for more

Source: Linda Schlemmer, DWD

Dust in the weather forecast

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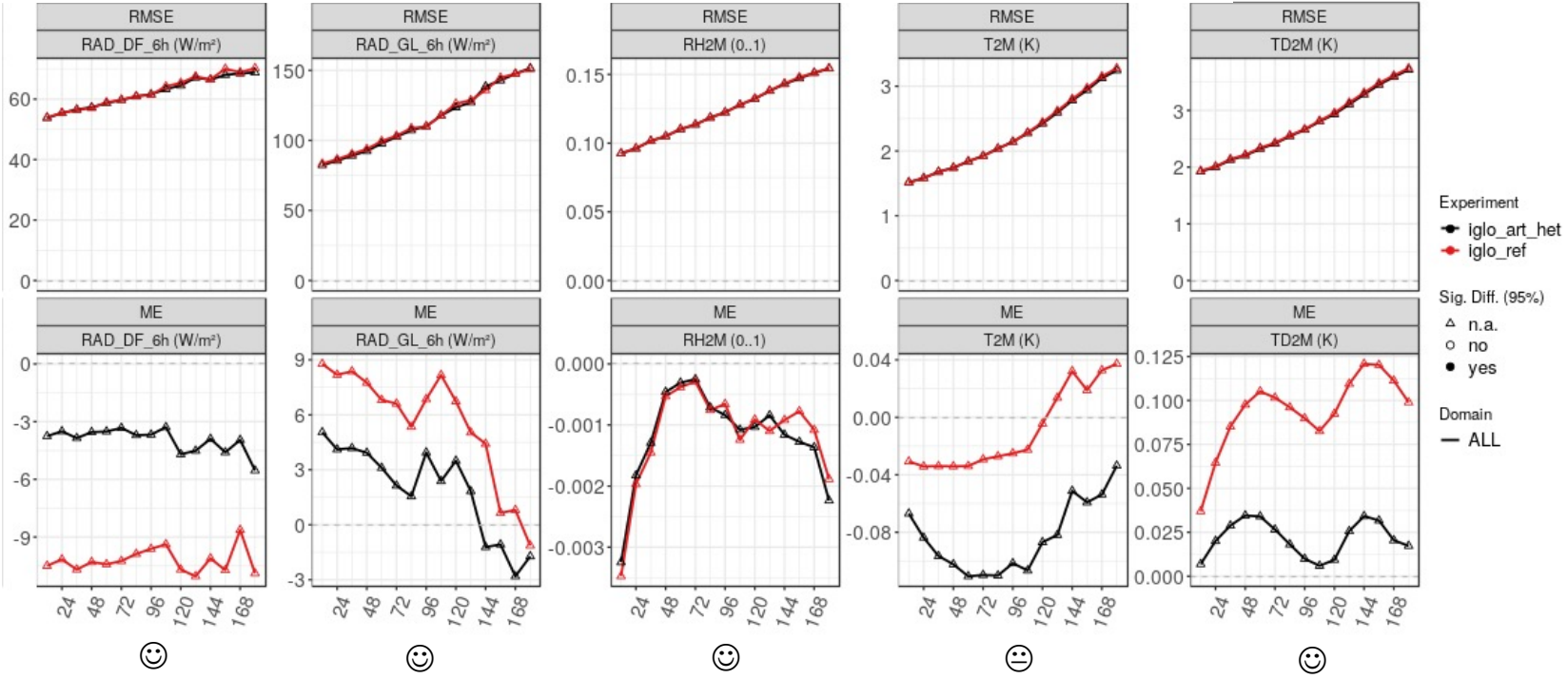
2022/04/18 00UTC – 2022/08/01 00 UTC, all runs

RMSE

BIAS



☺ ☺ ☺ 😐 ☺

Source: Linda Schlemmer, DWD

PermaStrom PerduS

Dust in the weather forecast ☺

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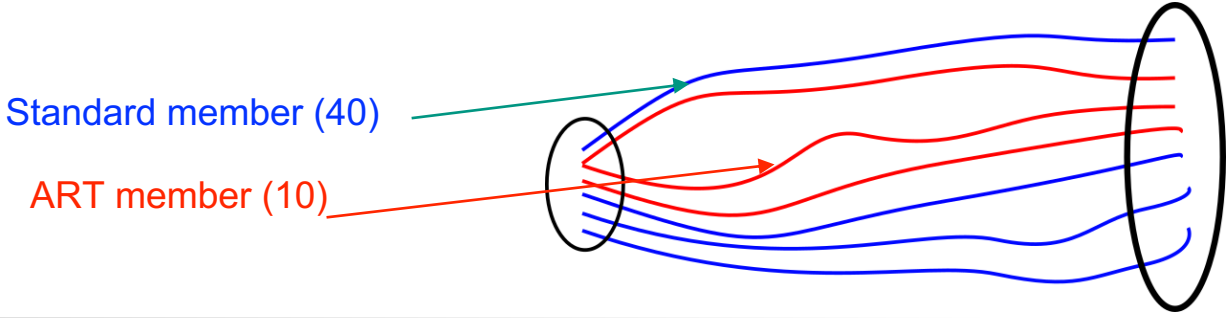
- Several individual case studies confirmed the benefits of the prognostic dust (ICON-ART) for the radiation forecast and the associated PV power forecast.
- This motivated the untroduction of ICON-ART mixed ensemble to share these benefits with the entire energy industry.
- Final steps are ongoing, expected to be public by 01.12.2023

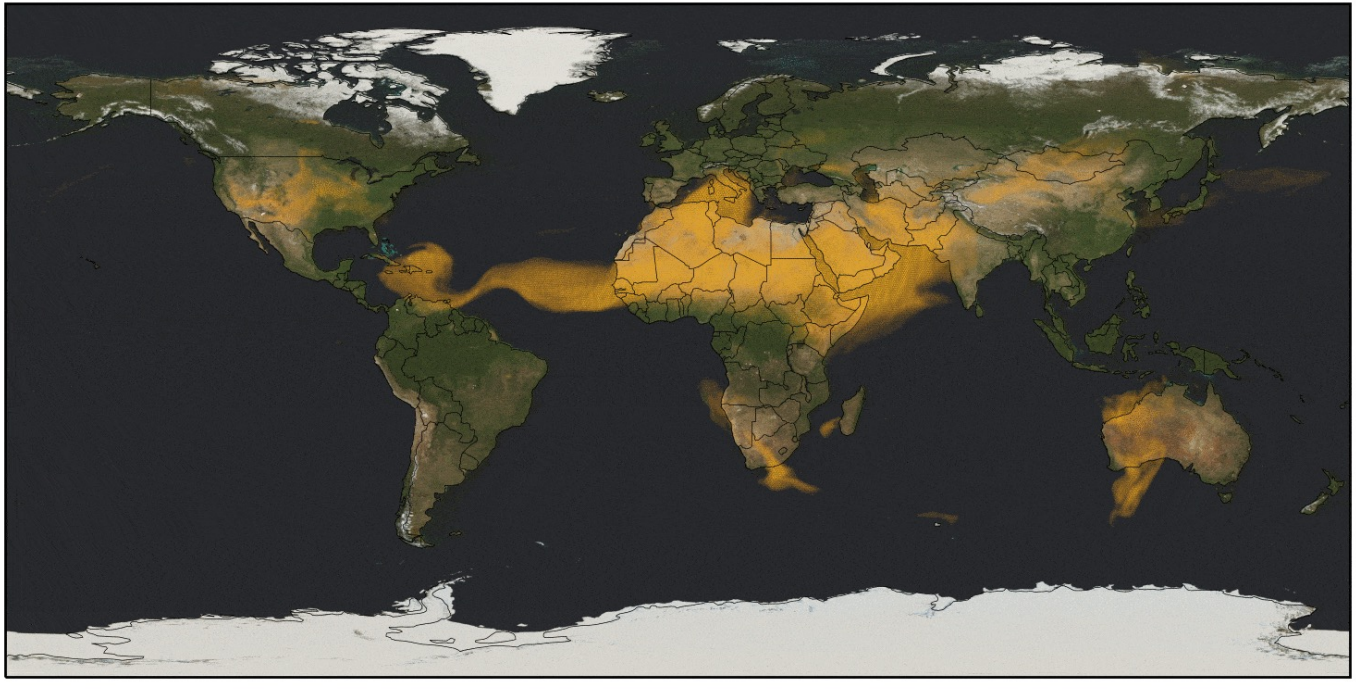


Source: Linda Schlemmer, DWD

PermaStrom PerduS

Aerosol events as natural experiments

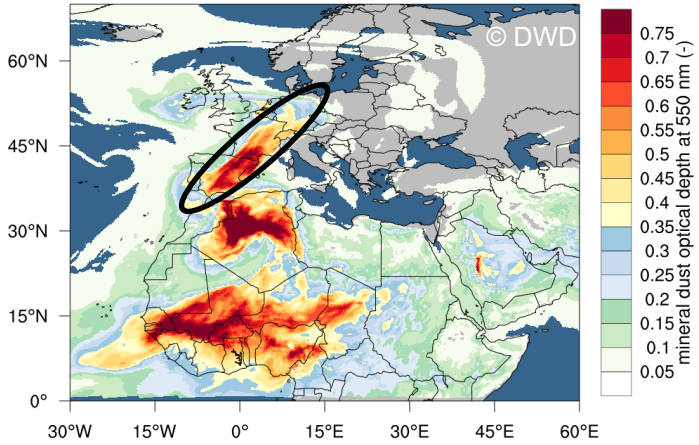
22-06-2019 00:00



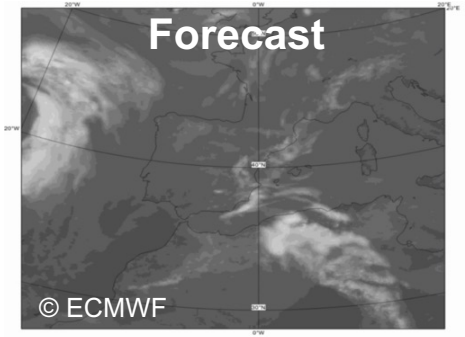
Dust Sea Salt Wildfire aerosols

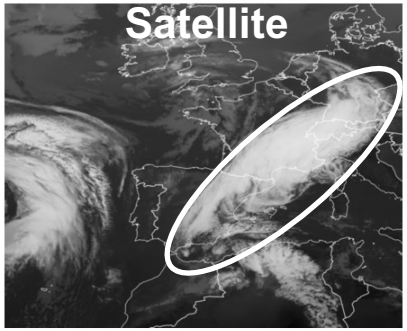
The missling cloud on 3. März 2021

Dust optical depth

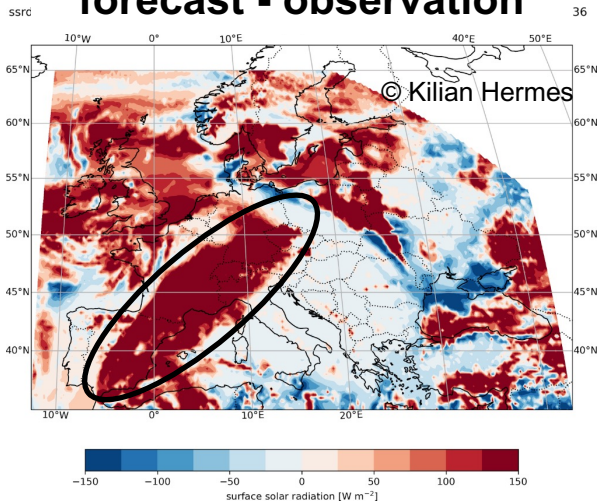


Clouds





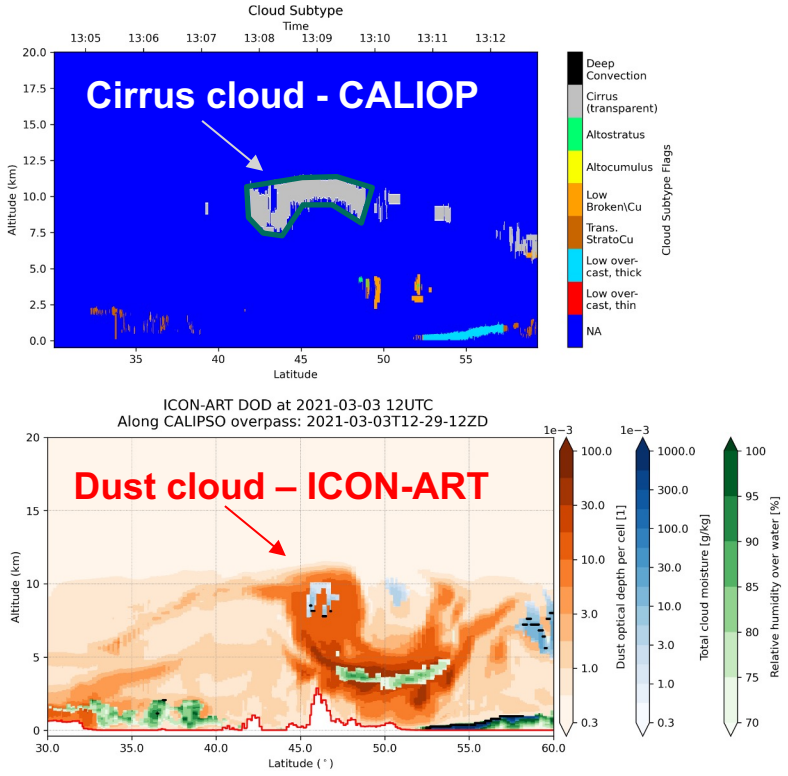
Solar radiation forecast - observation



 Source: ECMWF, DWD and METEOSAT (SIS, SAHRA-2)

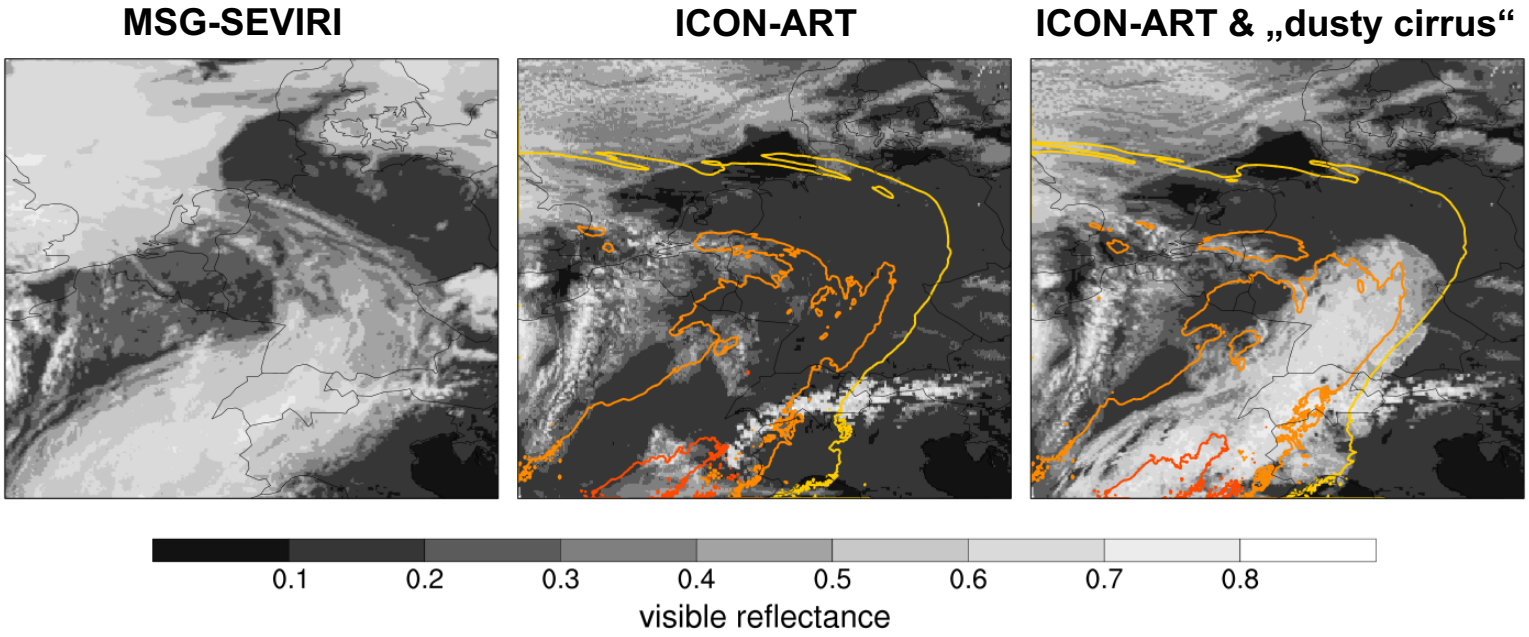
Coincidence or Dusty-Cirrus?

- On 03.03.2021 CALIOP satellite shows a cirrus cloud above the dust plume.
- During dust-infused baroclinic storms the mineral dust can reach the upper troposphere and affect, or even cause, the formation of cirrus clouds (Rieger et al., 2017; Weger et al., 2018; Ansmann et al., 2019).
- This can cause extended optically thick cirrocumulus decks known as “dusty-cirrus”.



Hermes et al. (2023) under review.

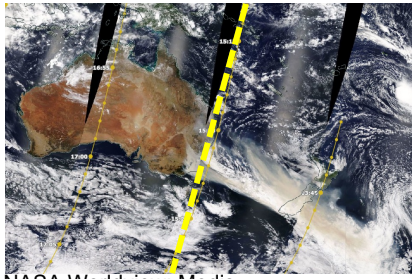
„Dusty Cirrus“ on 03.03.21 12:00 UTC



80% bias reduction in downward SW radiation

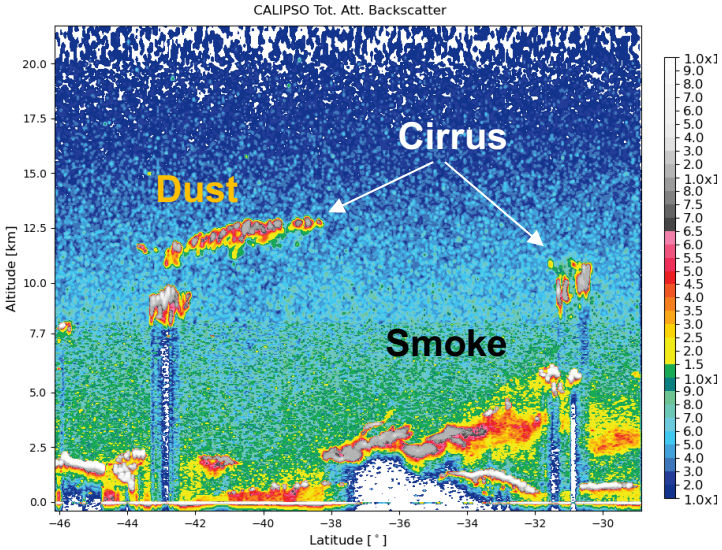
Seifert et al. 2023 (ACP)

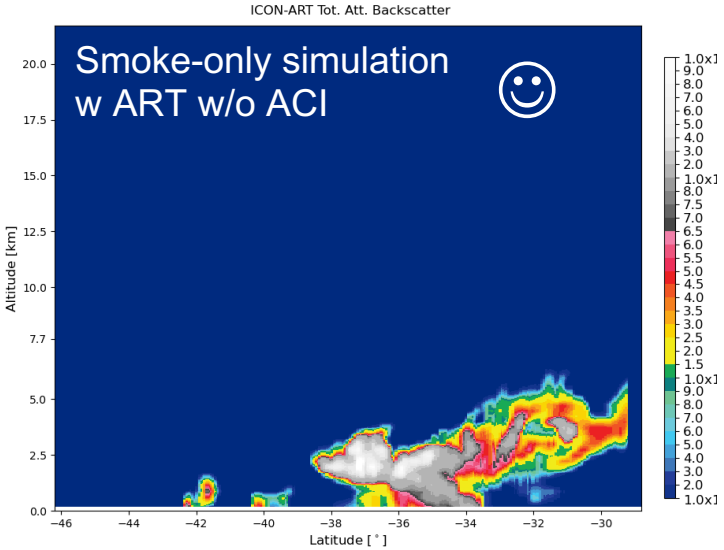
Australia's Black Summer 2019/20



NASA Worldview: Modis

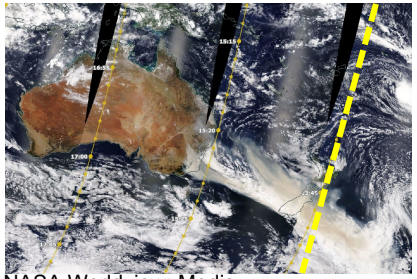
CALIOP view on 01.01.2020 15:30 UTC
(Dusty- and smoky-cirrus?)





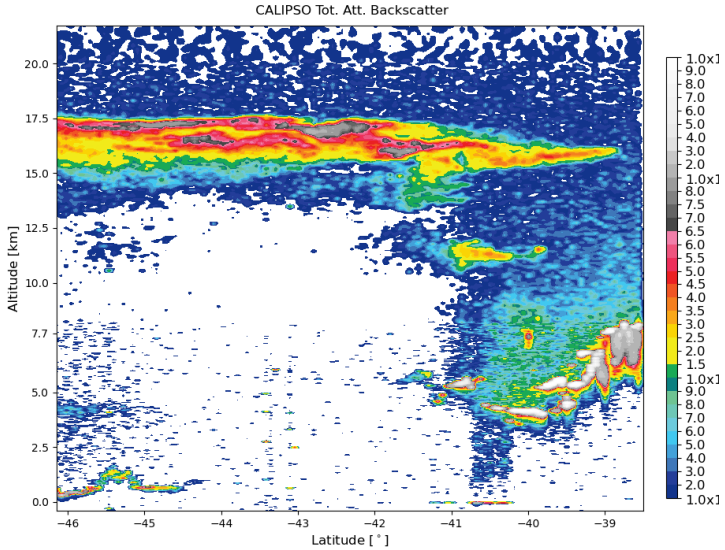
Lisa Muth et al. 2023 (in prep)

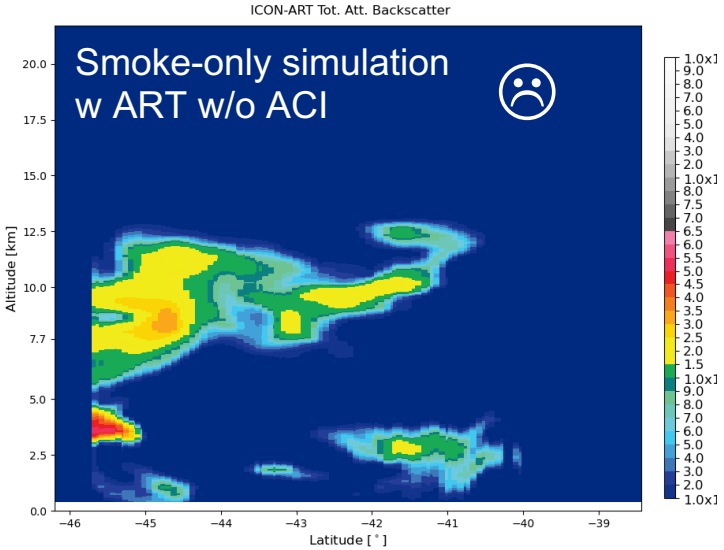
Australia's Black Summer 2019/20



NASA Worldview: Modis

CALIOP view on 01.01.2020 13:30 UTC
(Missing source/processes?)



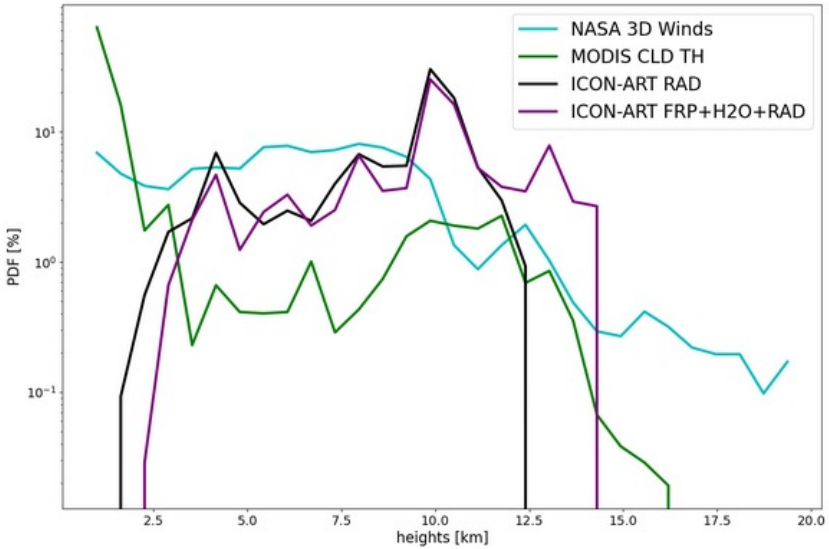


Lisa Muth et al. 2023 (in prep)

Plume top heights on 01.01.2020 03:30 UTC

Plume height is affected by:

- (Atmospheric conditions)
- Fire radiative power (FRP)
- H_2O emissions
- Aerosol-Radiation interaction (self-lofting)



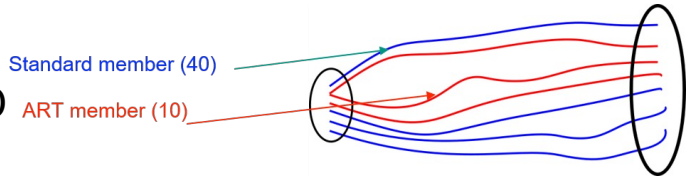
Challenges:

- What is the truth?
- Missing/underestimated fires
- Heat flux and model resolution
- Plume rise / injection height

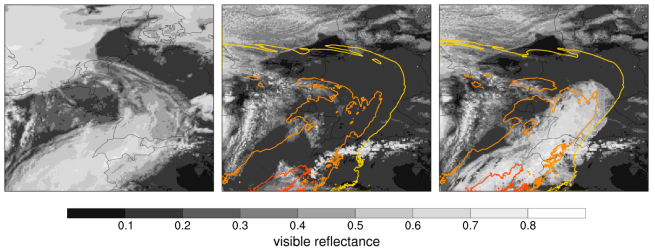
Lisa Muth et al. 2023 (in prep)

Summary

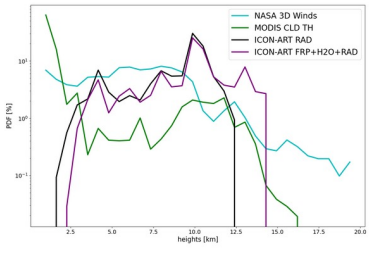
- ART is developed consistent and in close collaboration with ICON → Weather forecast @DWD with prognostic dust aerosols (w ARI, w/o ACI).



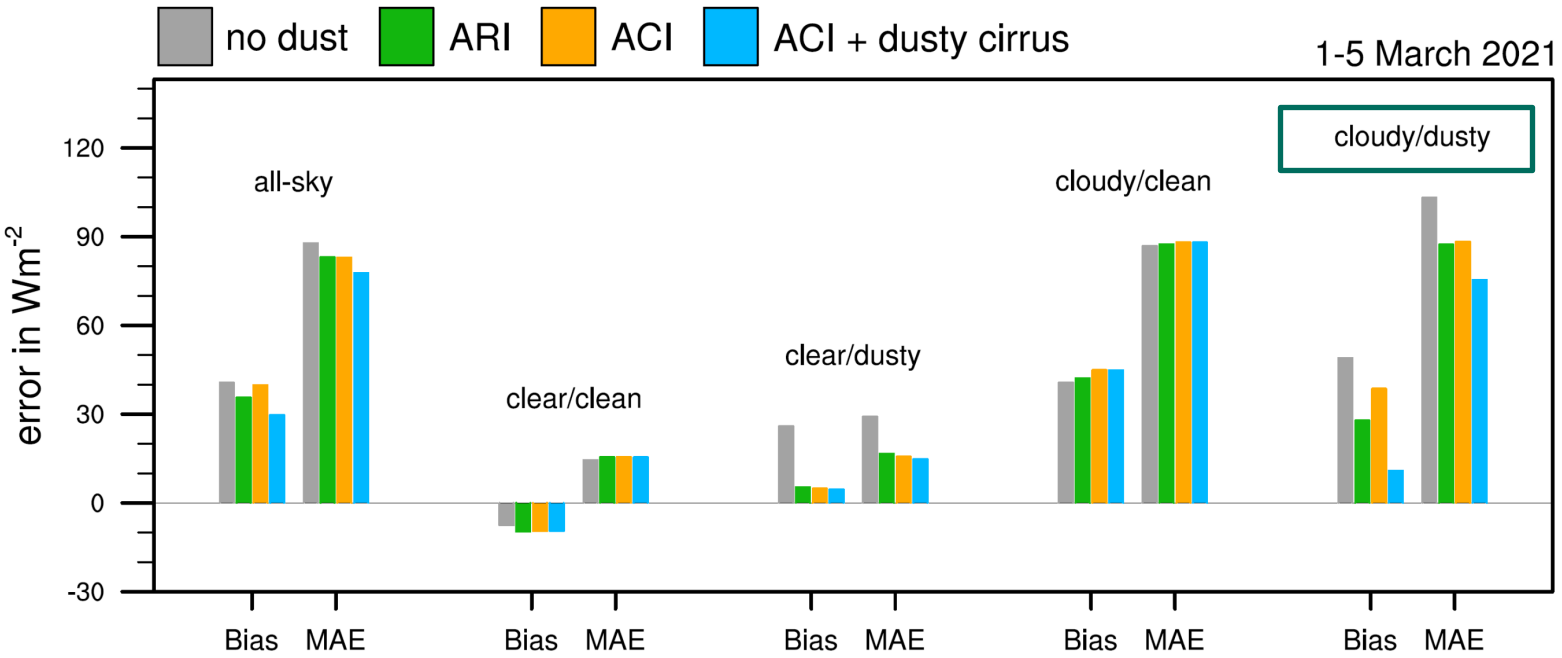
- A sub-grid parameterization enables the formation of the dusty cirrus in model and reduces PV prediction errors significantly.



- Heat and H_2O fluxes improve the smoke plume height but still not well enough compared to the observations.



ICON(-ART) vs CERES downward SW radiation at the surface



Seifert et al. 2023 (ACP)