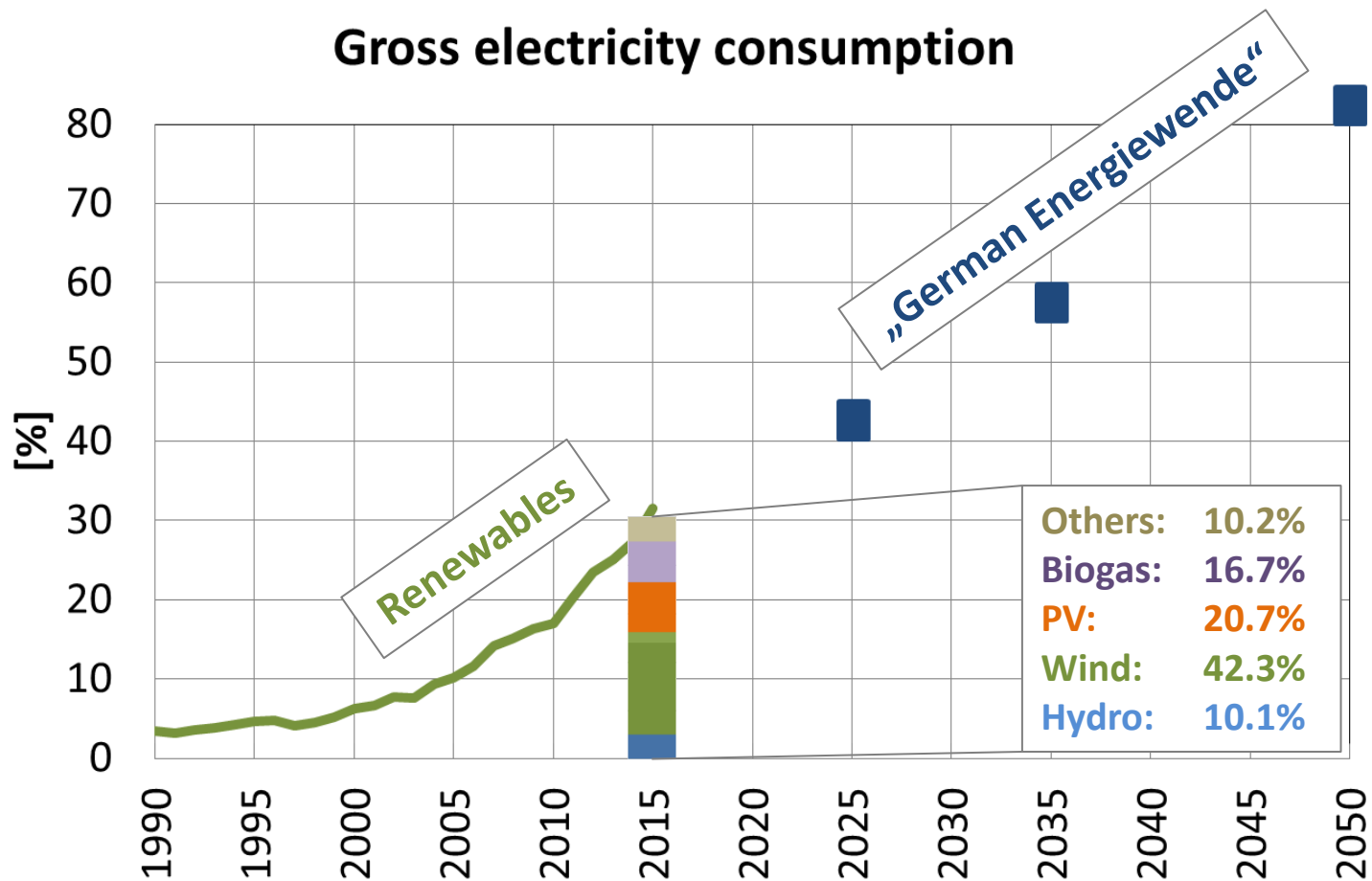


Forecasting the reduction in photovoltaic power production during Saharan dust outbreaks



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

- Motivation
- Project PerduS
- Modelling system ICON-ART
- First results
 - Dust emission
 - August 2012 dust outbreak
- Conclusion



Data source: BMWI: http://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html

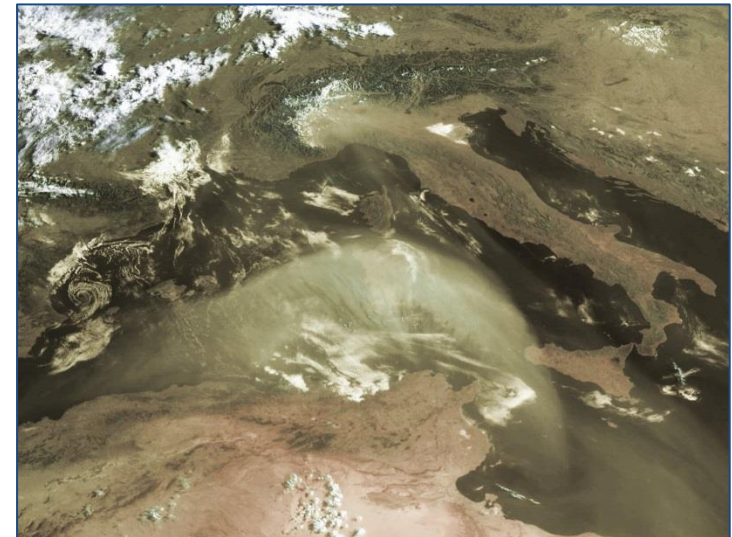
On sunny days, up to 50% of instantaneous energy demand covered by PV

Flentje et al., 2015:

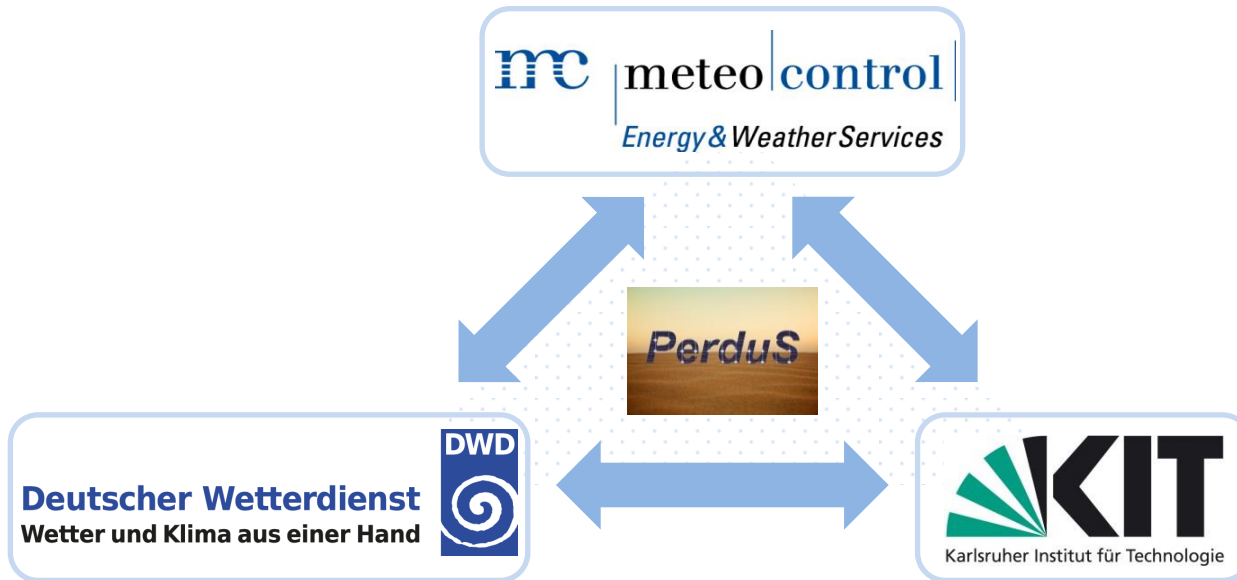
- 5 – 15 Saharan Dust events/year at Hohenpeißenberg (1997 – 2013)
- Typical duration 1 – 3 days, maxima in spring and early autumn

Challenge for PV-power forecasting:

- NWP forecast errors due to aerosols:
 - direct, semi-direct
 - indirect
- Polluted PV-modules



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



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

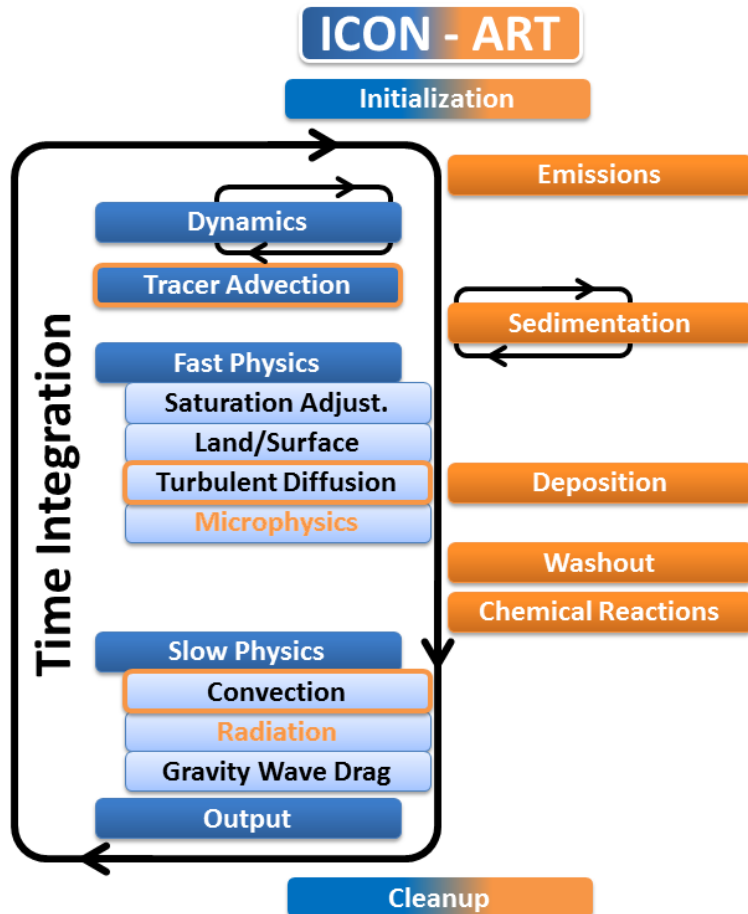
Main objective:

- 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

ICON and ART (Aerosols and Reactive Trace Gases)



- Online coupled system of **ICON** and **ART** modules
- +6 prognostic equations for mineral dust
 - Specific number and mass mixing ratio for 3 modes
- Transport and diffusion for ART tracer as for atmospheric variables (such as moisture)

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

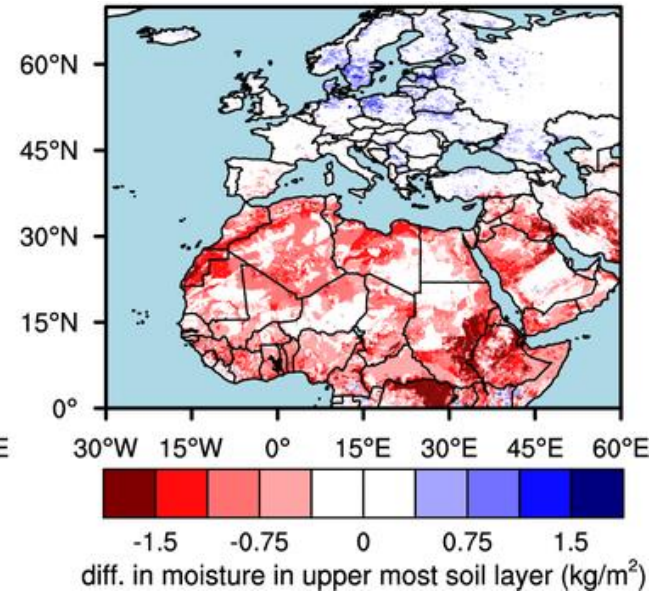
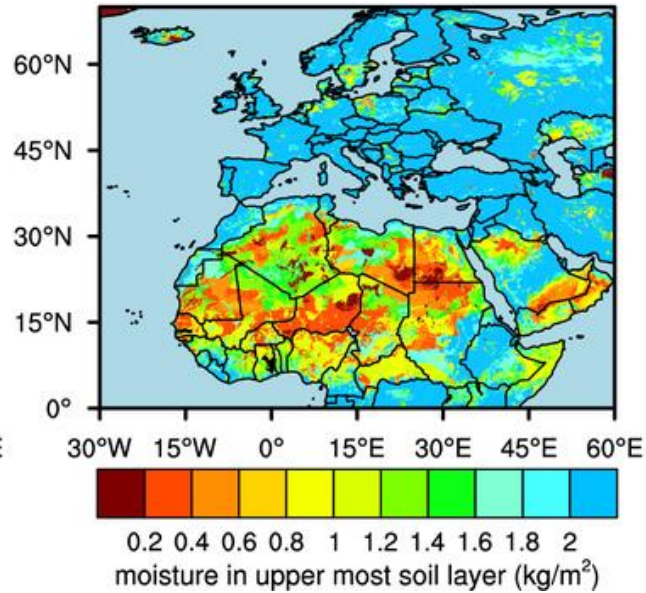
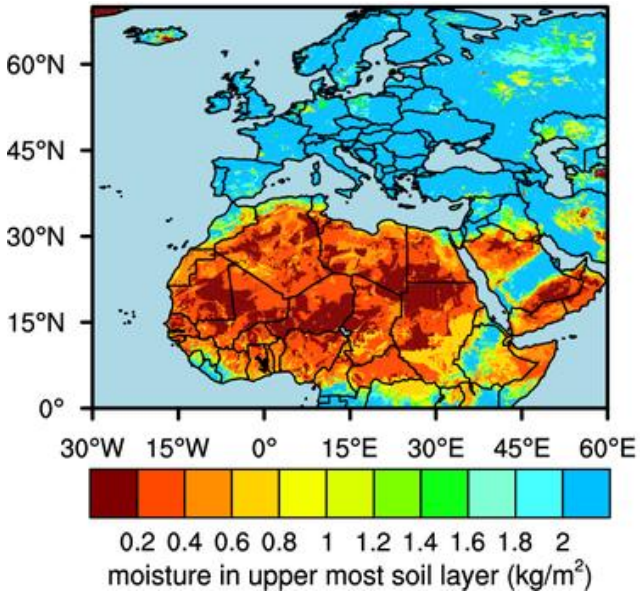
Sensitivity studies concerning Dust Emission

Soil-moisture dependency

new bare soil
evaporation scheme

old version

difference
(new - old)



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

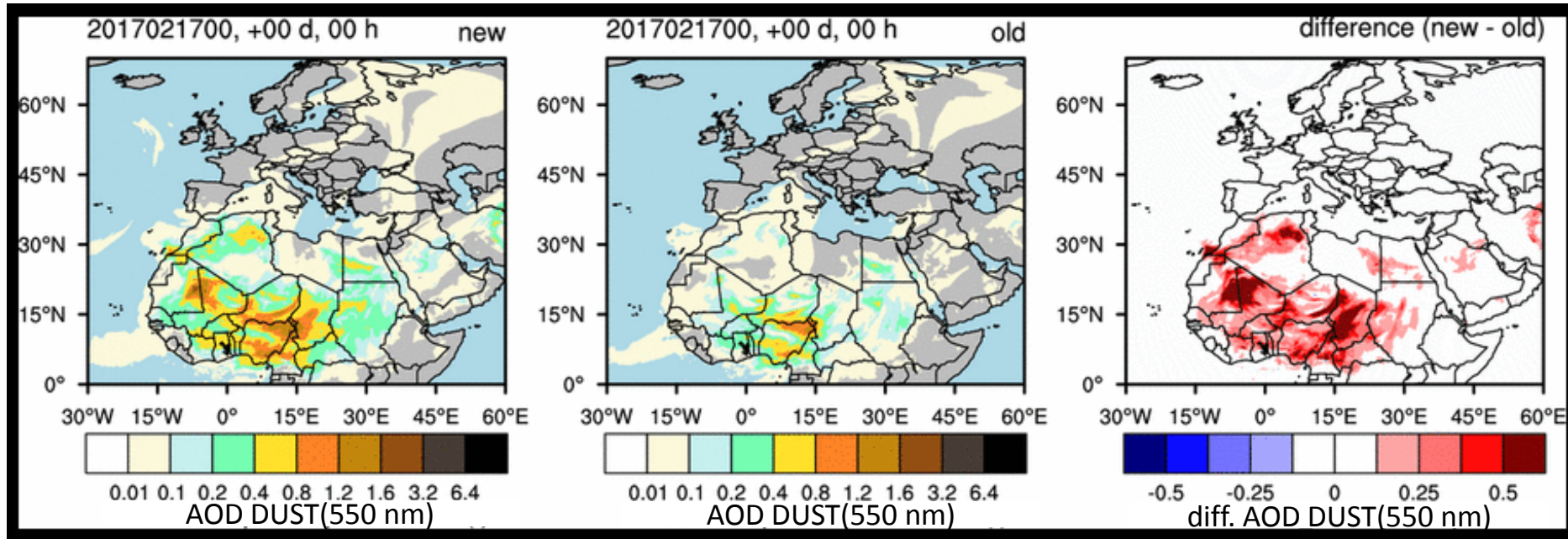
17 February 2017 00 UTC

Soil-moisture dependency

New bare soil
evaporation scheme

Old version

Difference
(new - old)



Another study has shown:

**50% drier soil leads to +64% more dust in the atmosphere after 12 hours
(no dust in the beginning)**

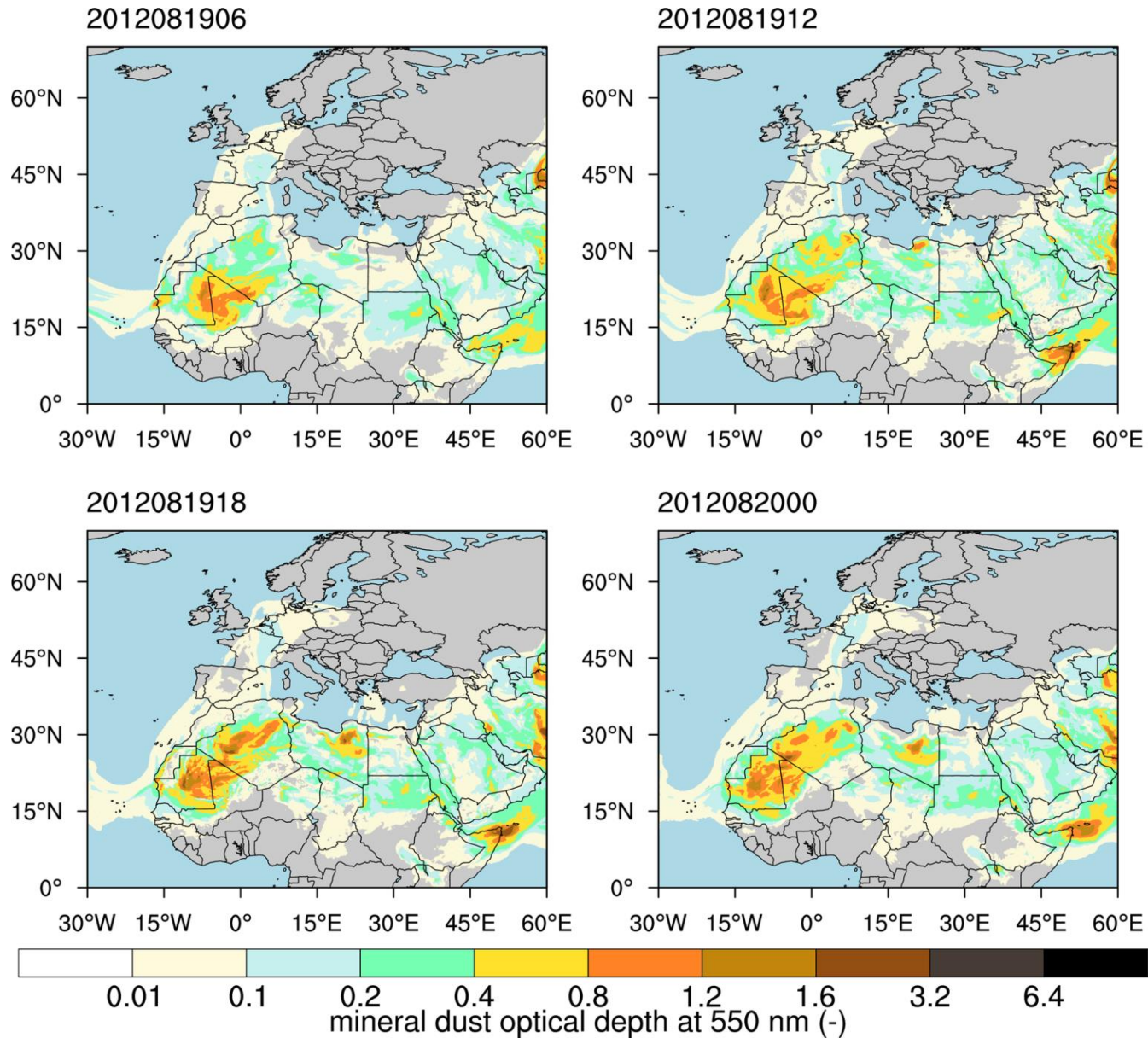
Aerosol radiation interactions

Sensitivity study concerning

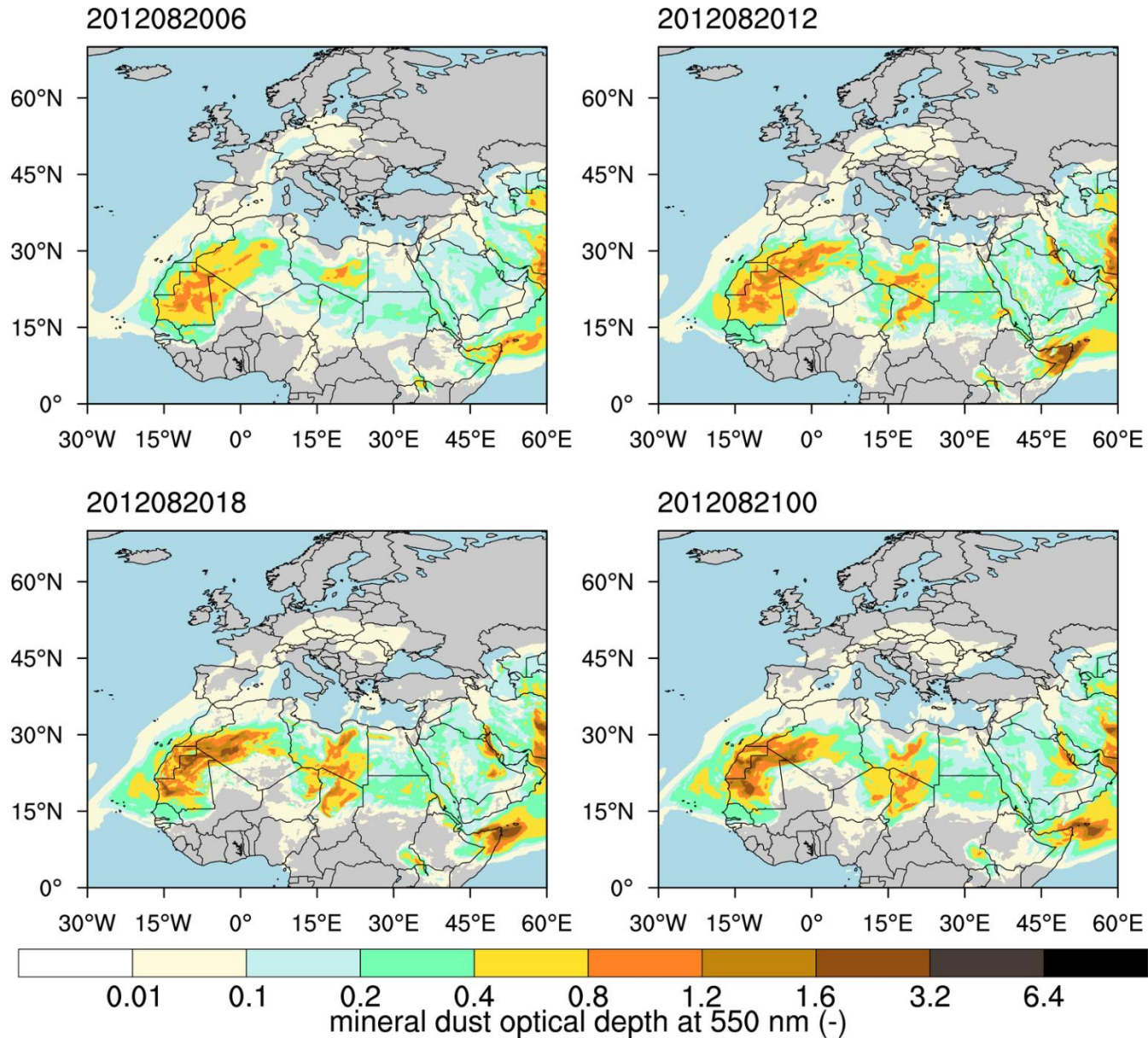
Clear Sky Case

August 2012

r3b07 (13 km) – 18 August 2012 00 UTC

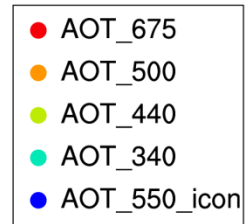
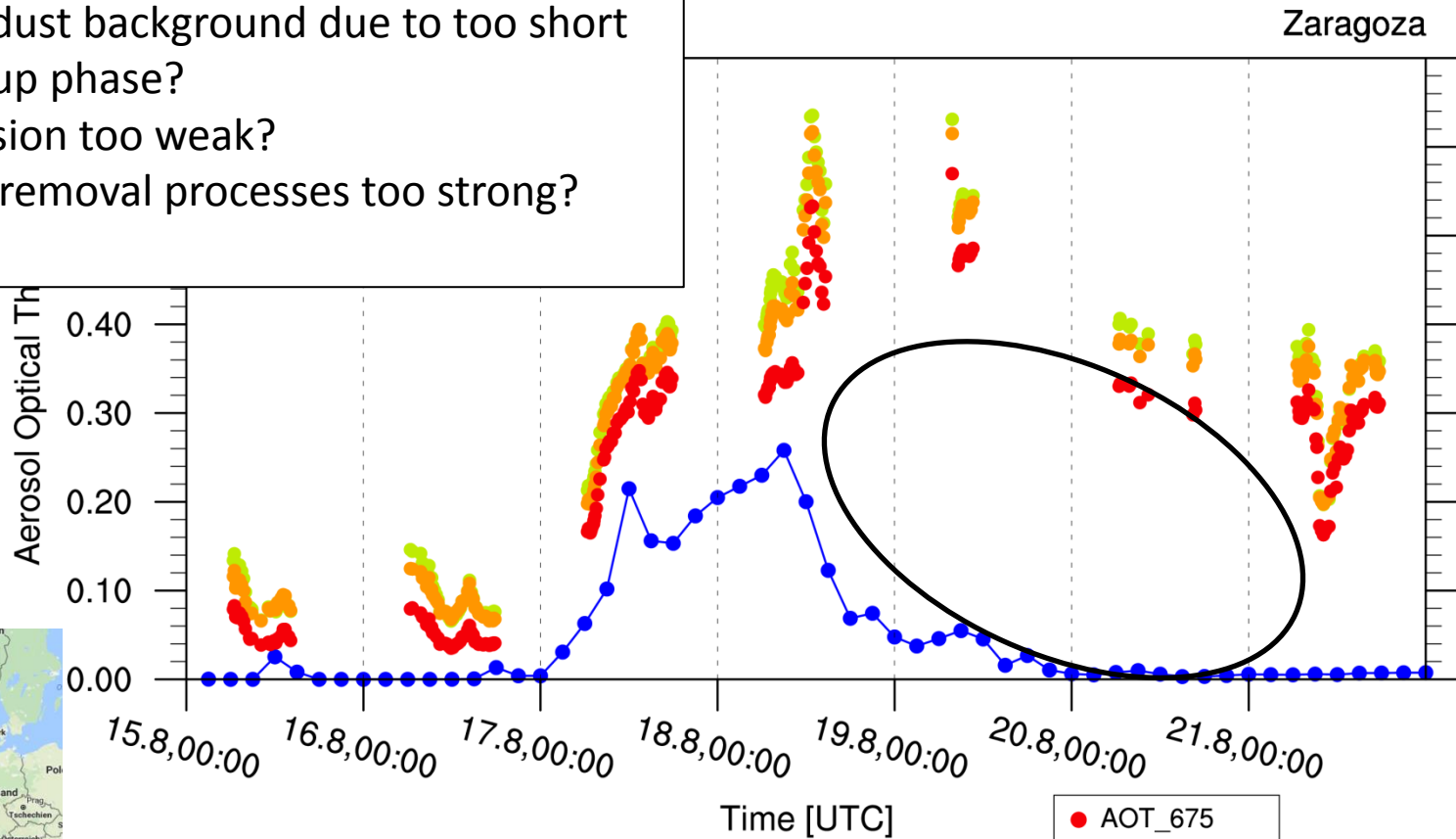


r3b07 (13 km) – 18 August 2012 00 UTC



Comparison to AERONET data

- Low dust background due to too short spin up phase?
- Emission too weak?
- Dust removal processes too strong?
- ...



Gefördert durch:



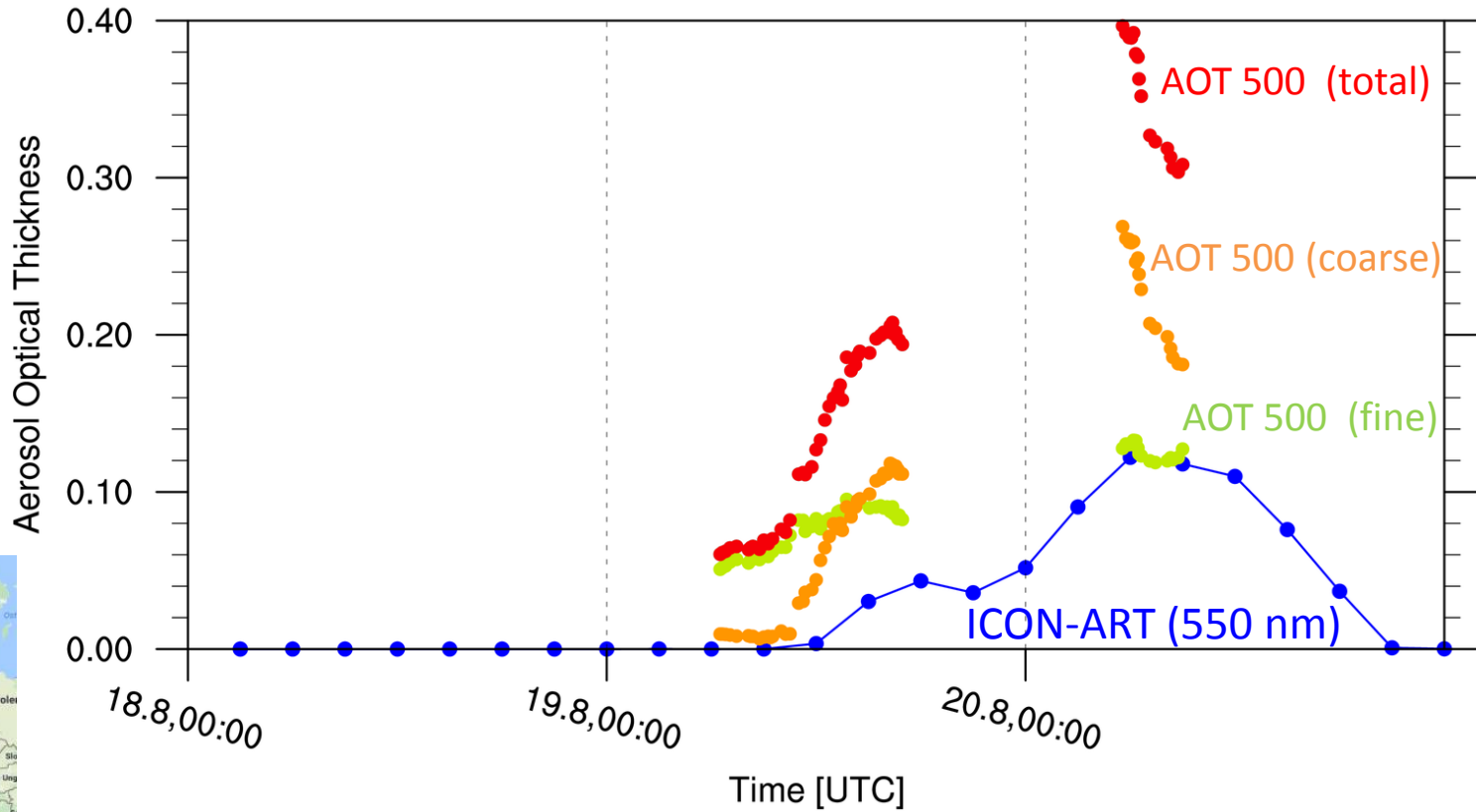
Photovoltaikertragsreduktion durch Saharastaub

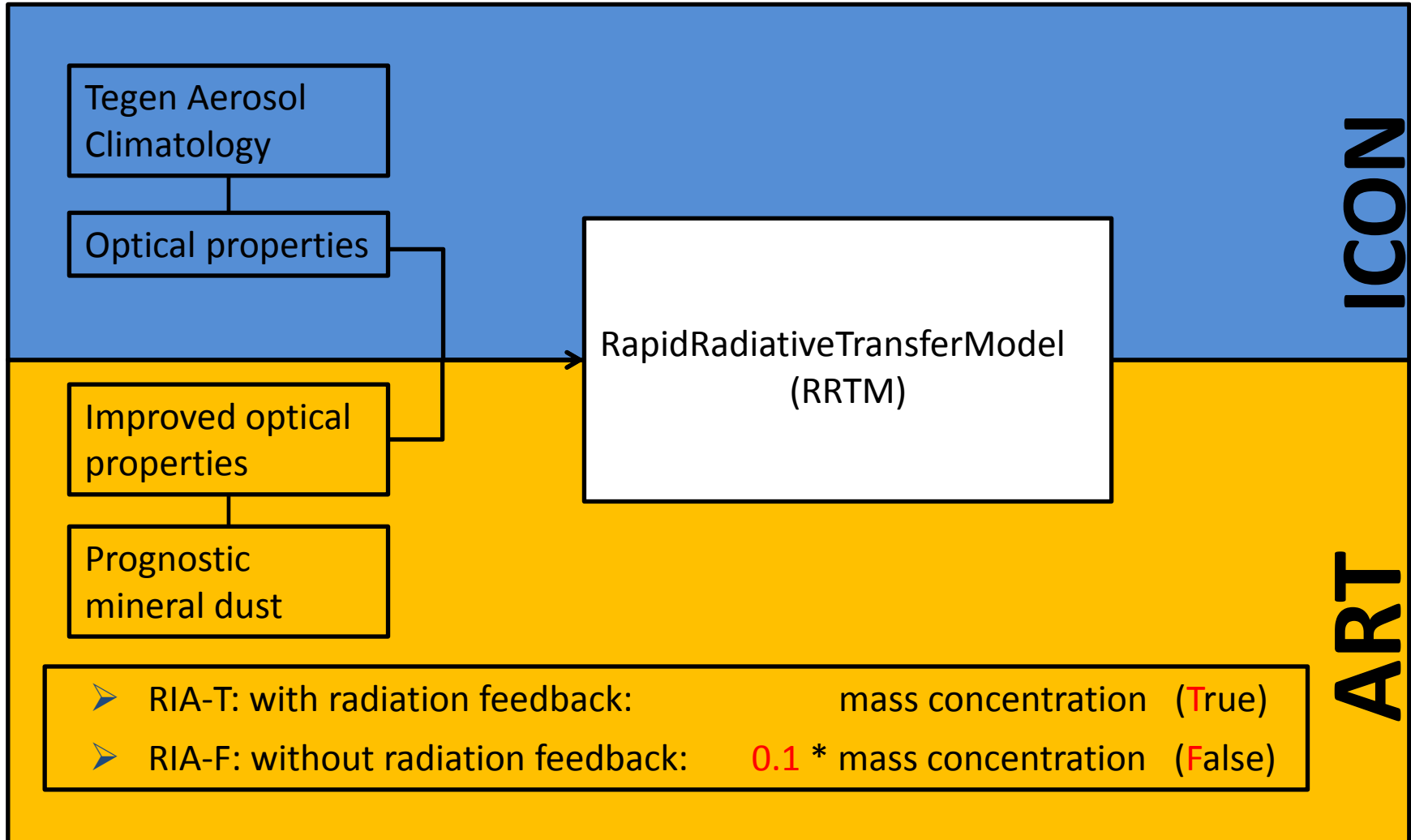


Comparison to AERONET data

ICON_r3b07

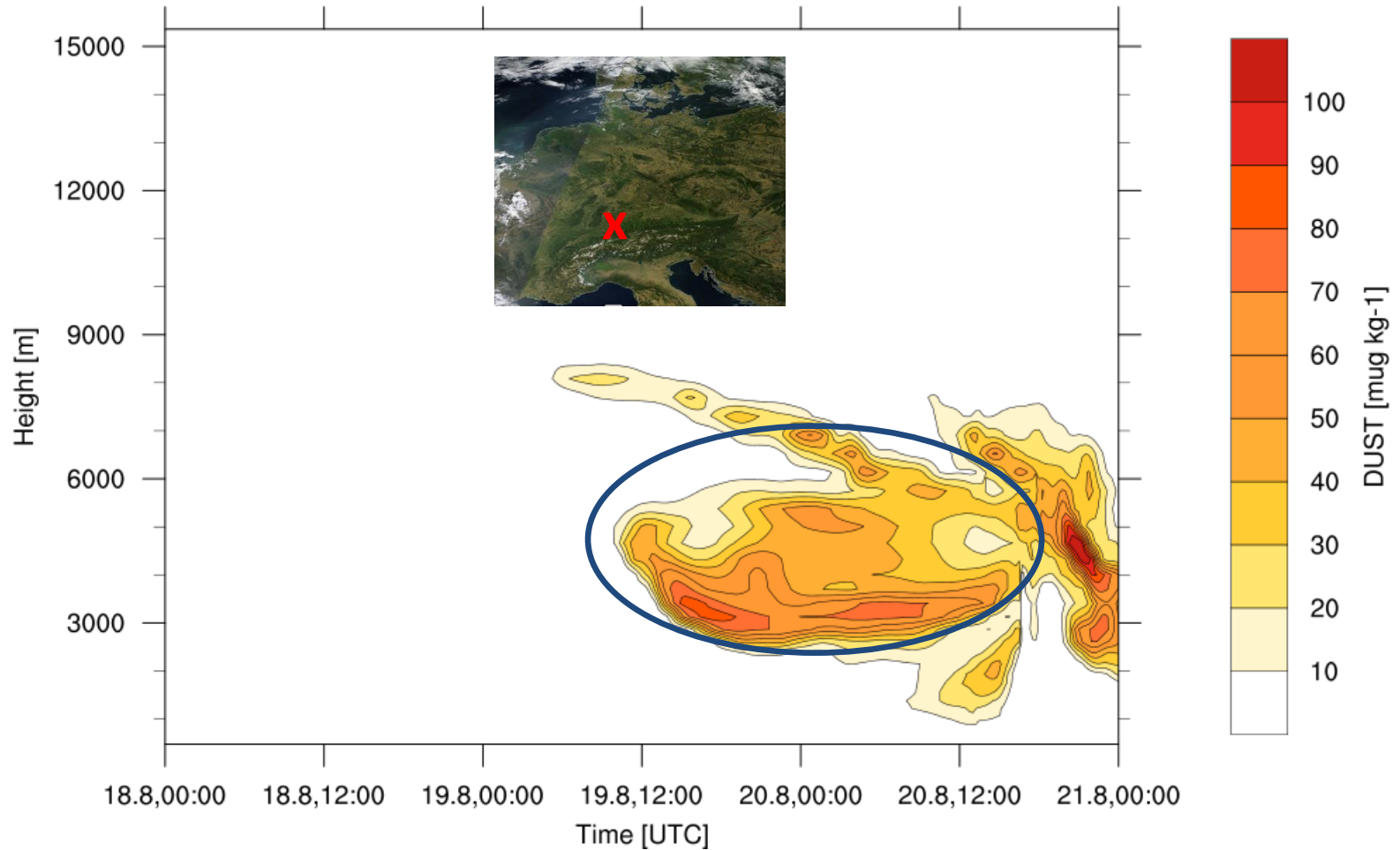
Leipzig



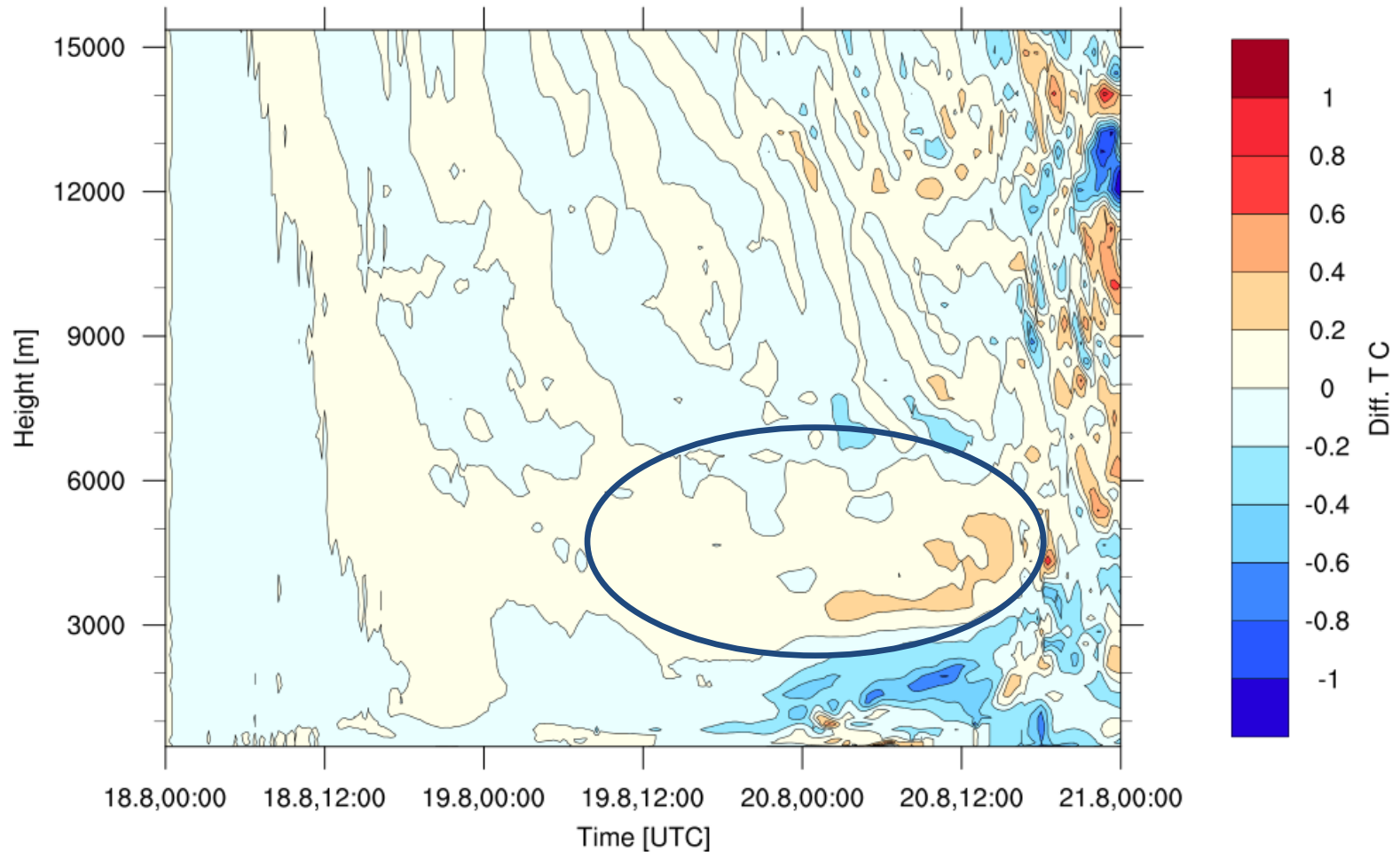


ICON-ART, fcst-run: 2012081800, Konstanz

RIA-F



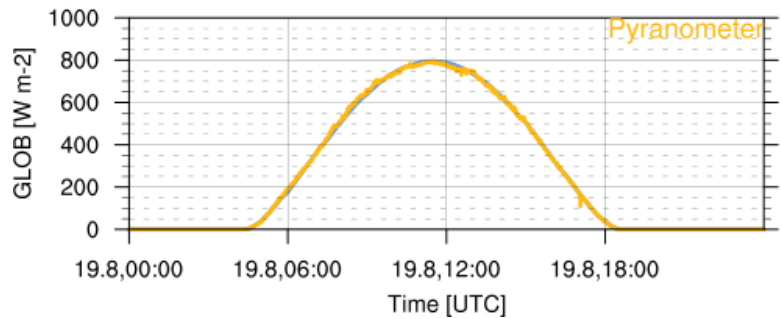
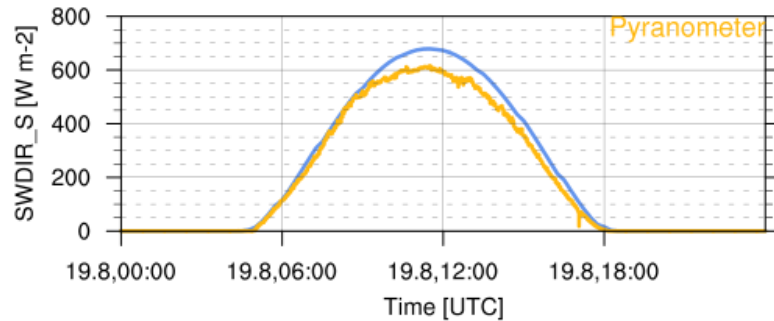
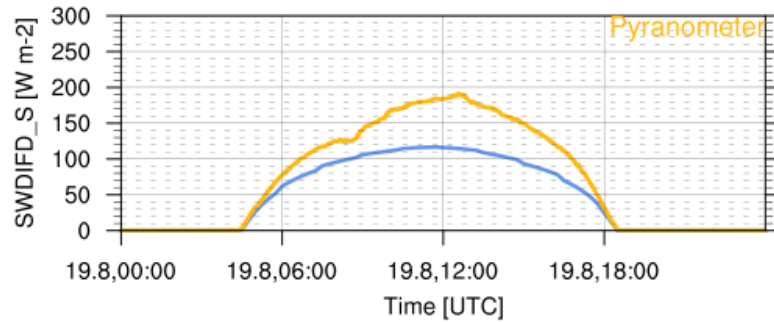
ICON-ART, fcst-run: 2012081800, Konstanz, T_minus_F



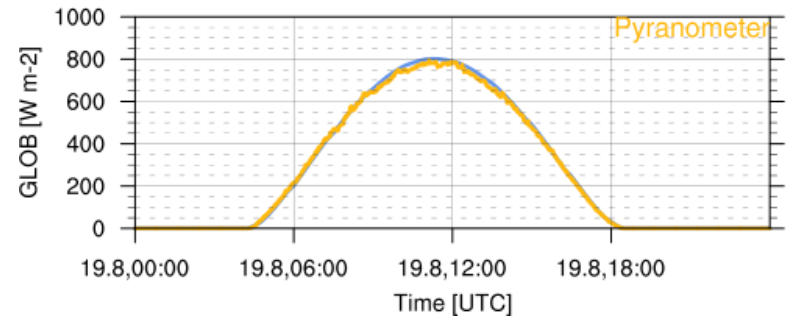
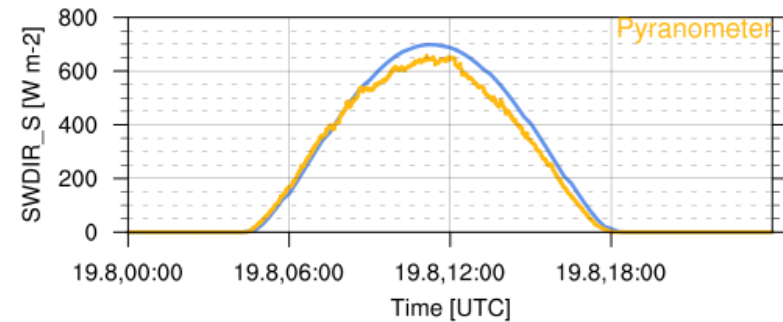
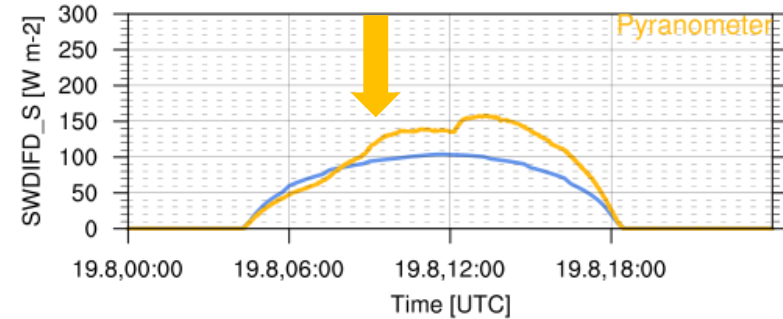
Dust-Atmosphere interactions

- RIA-F
- RIA-T

Mannheim



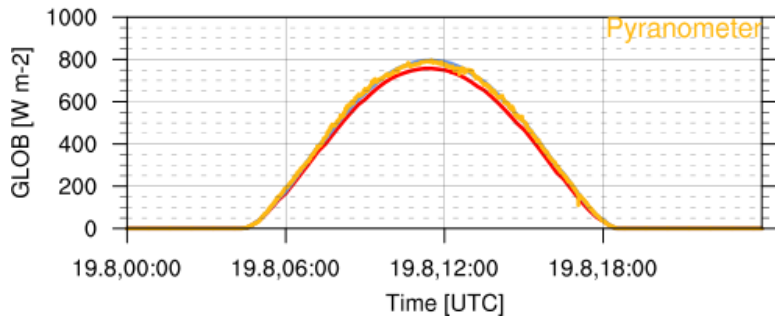
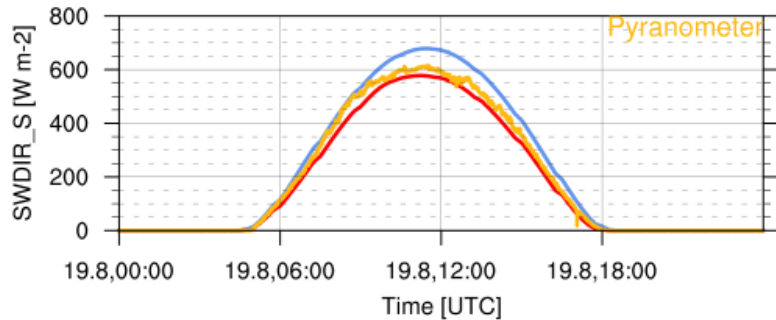
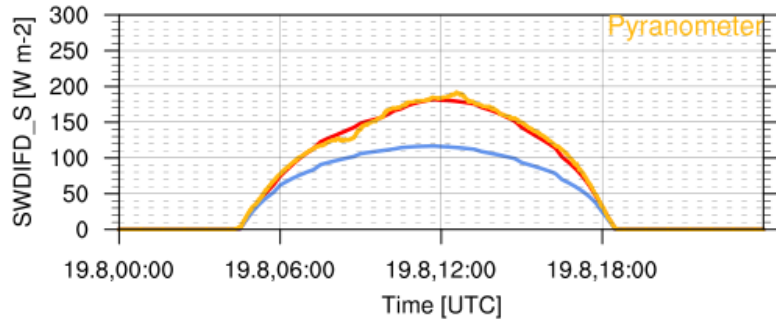
Meiningen



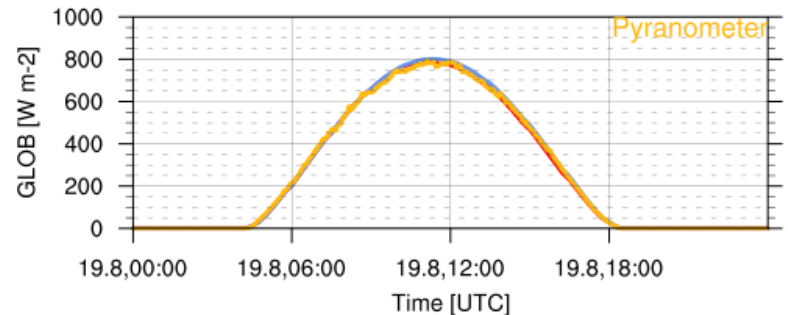
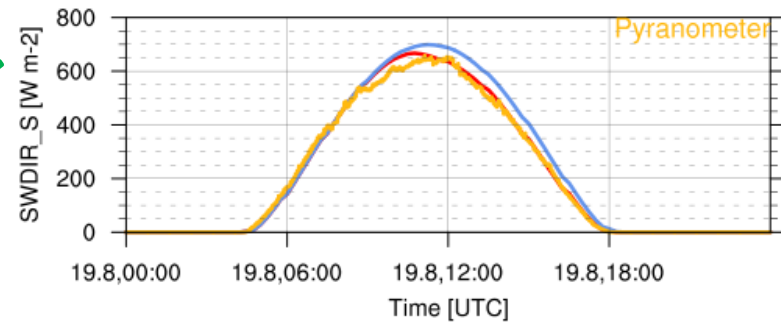
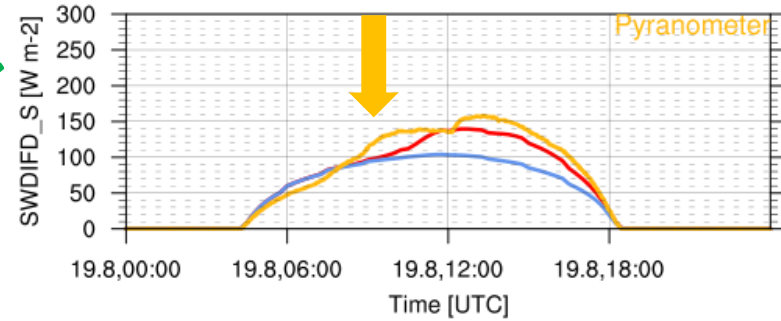
Dust-Atmosphere interactions



Mannheim

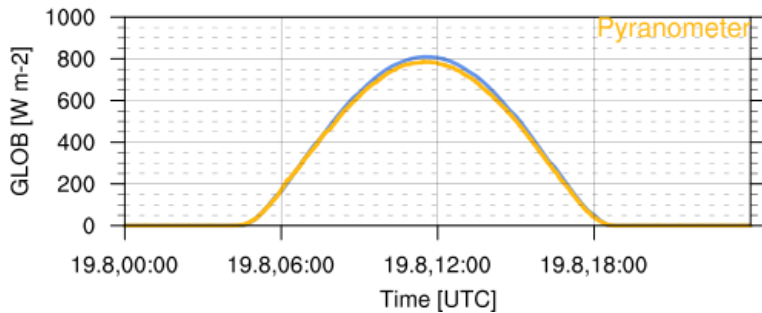
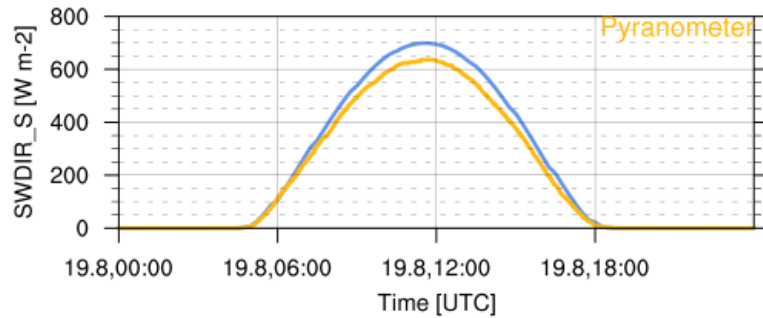
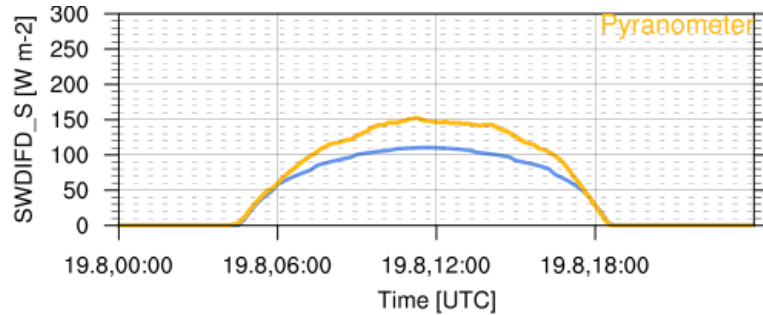


Meiningen

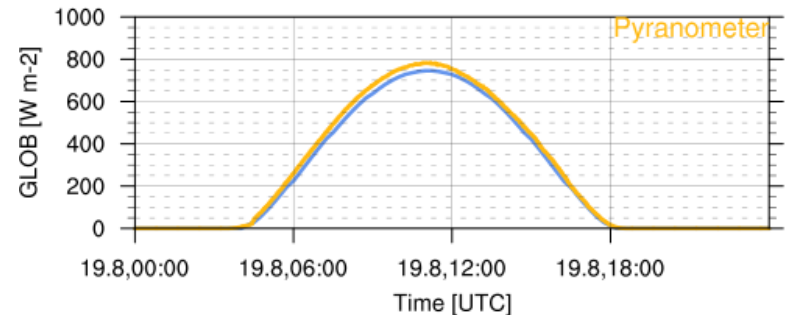
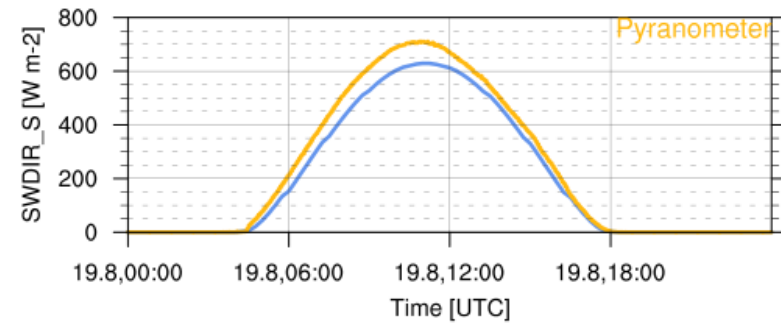
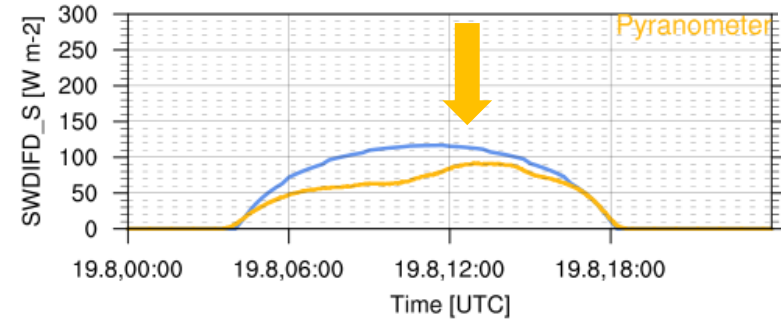


Dust-Atmosphere interactions

Saarbrücken

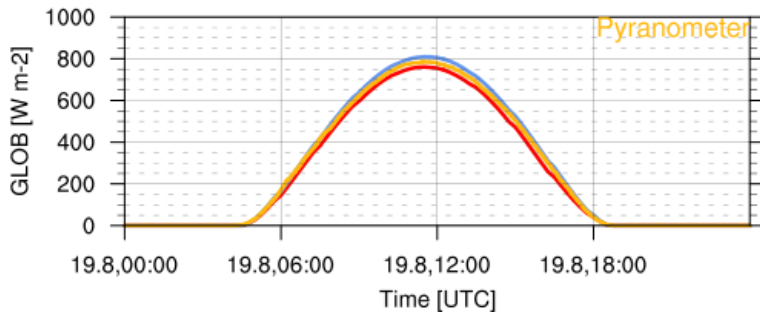
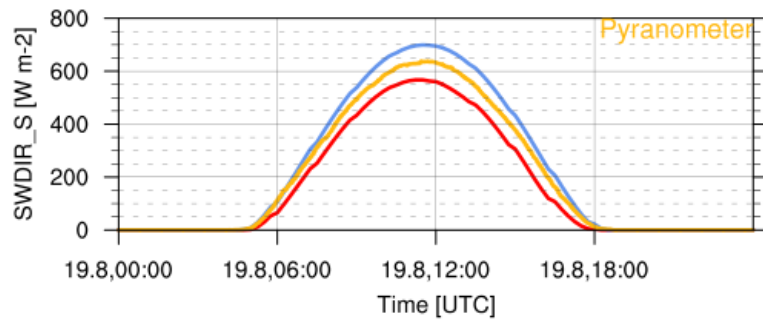
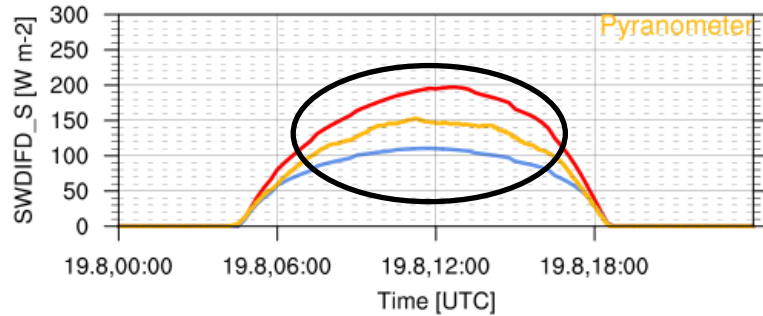


Lindenberg

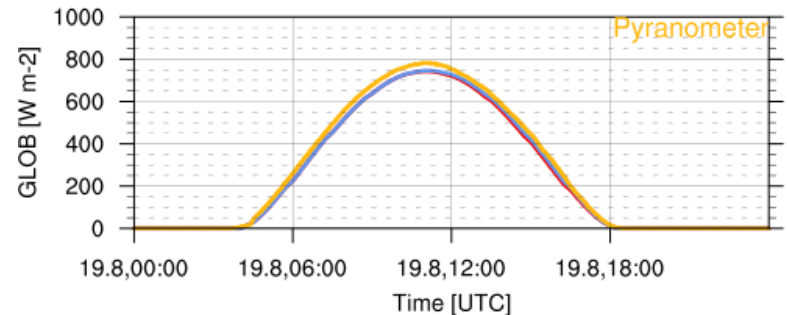
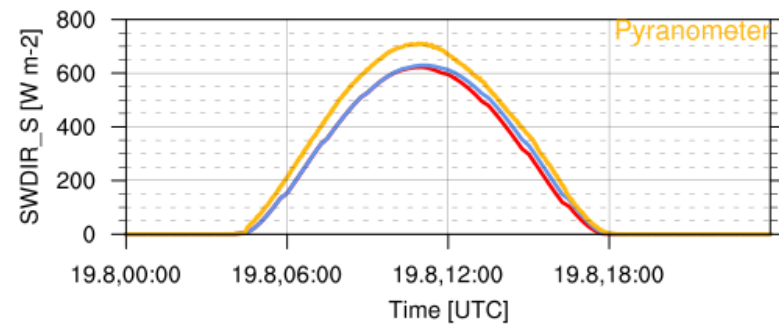
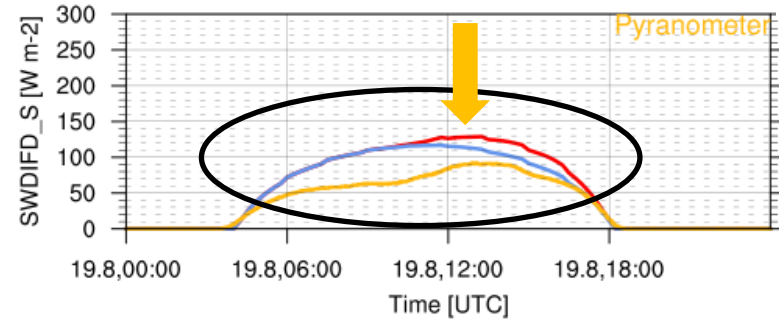


Dust-Atmosphere interactions

Saarbrücken



Lindenberg

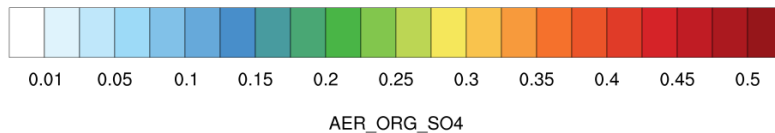
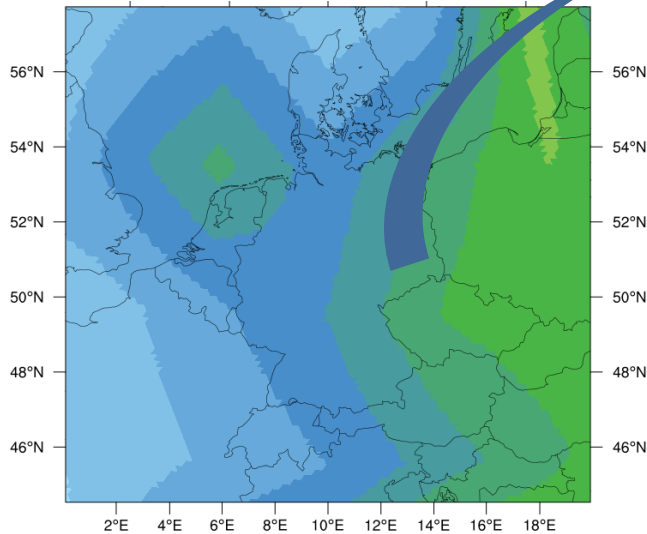


- RIA-F
- RIA-T

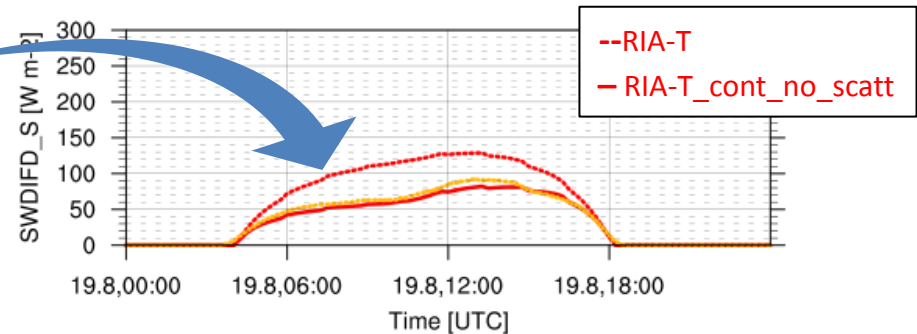
X

X

Tegen Aerosol Climatology for continental aerosols, August



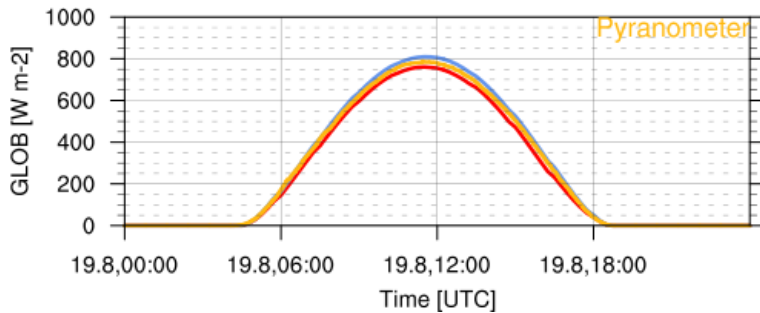
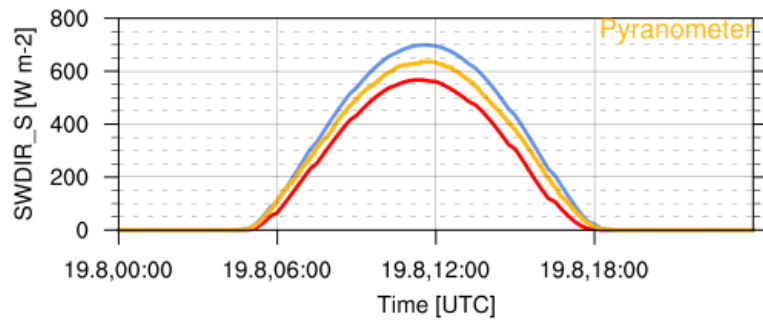
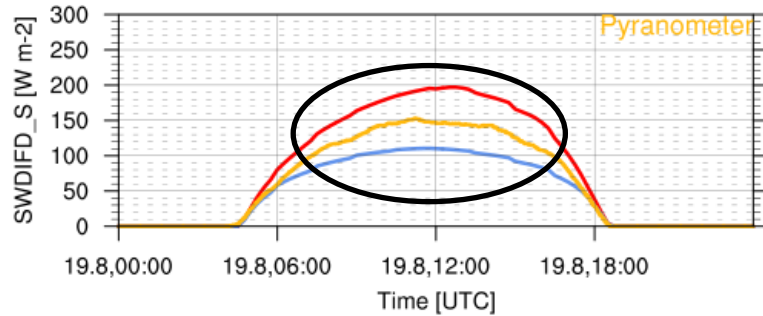
Lindenberg



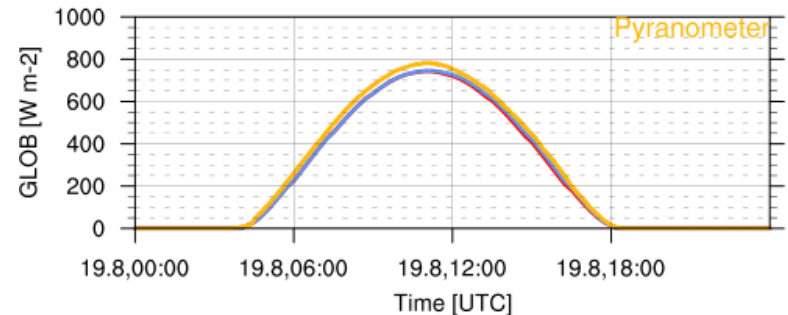
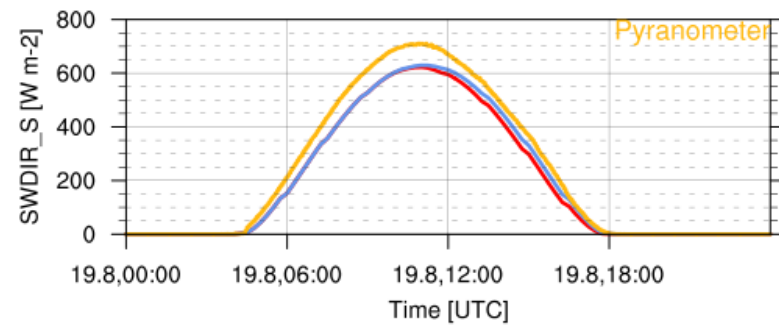
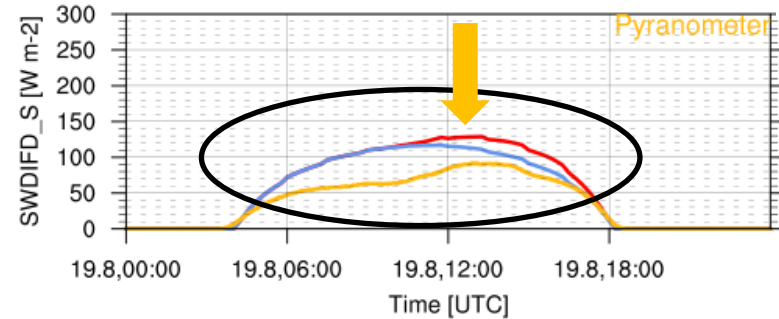
- ➔ Tegen AOD: **0.1 – 0.2**
- ➔ Observed AOD on clear sky days and after precipitation events: about **0.05**
- ➔ Scattering on continental aerosols:
➔ 50 W/m² diffuse radiation

Dust-Atmosphere interactions

Saarbrücken



Lindenberg



- RIA-F
- RIA-T

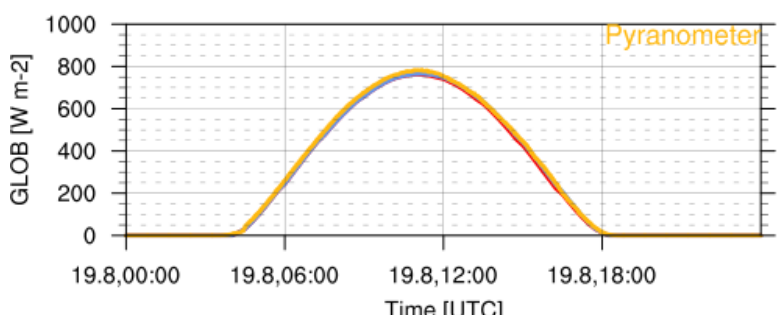
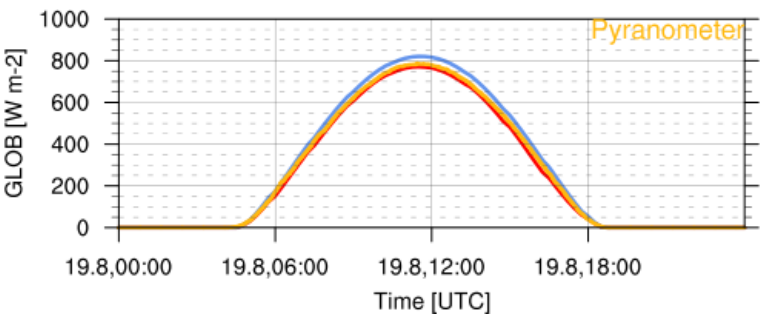
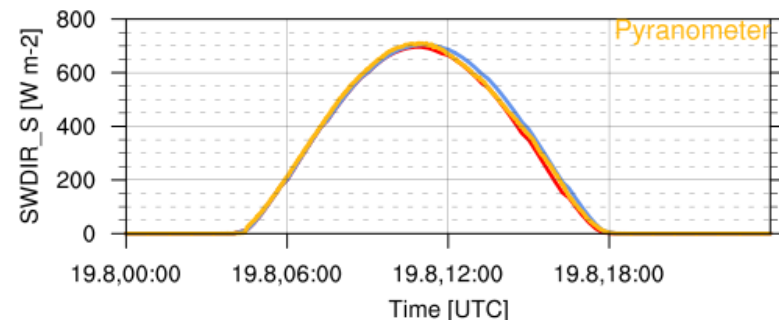
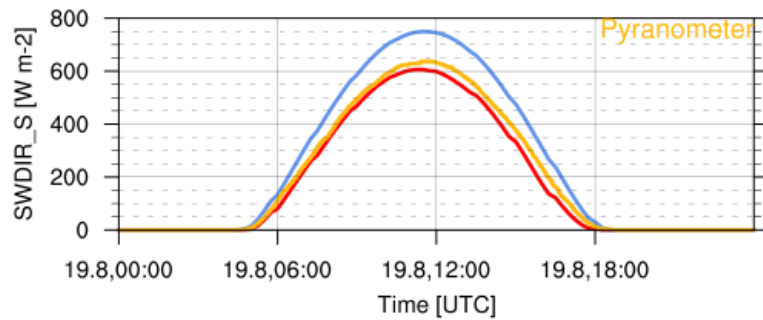
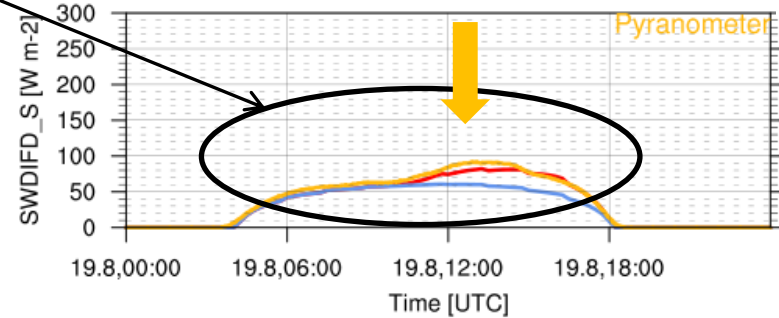
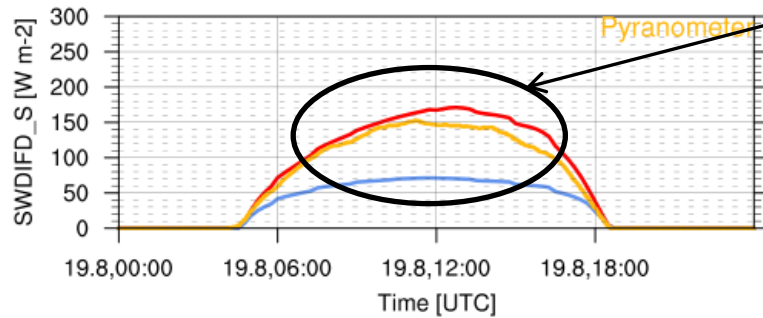
Dust-Atmosphere interactions

No scattering on continental aerosols

Saarbrücken

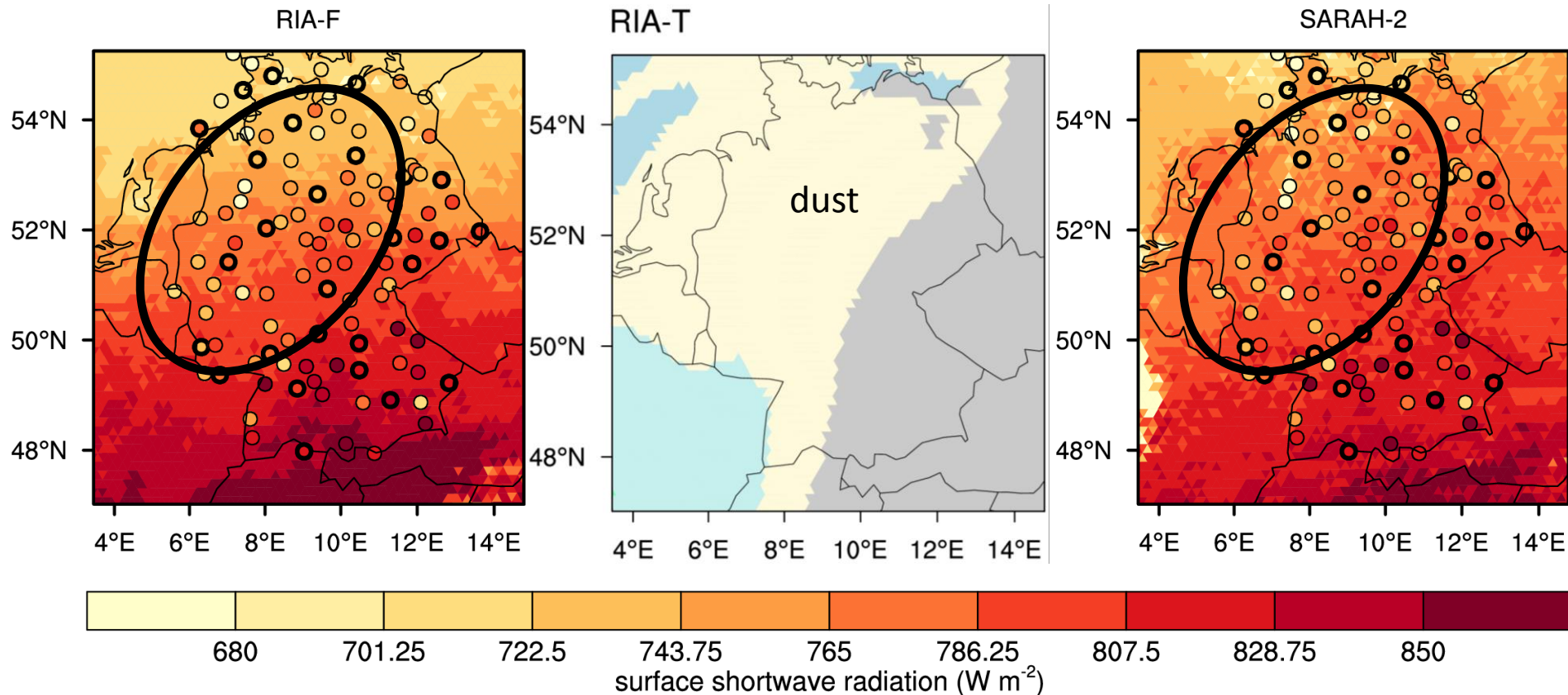
Lindenberg

● RIA-F
● RIA-T



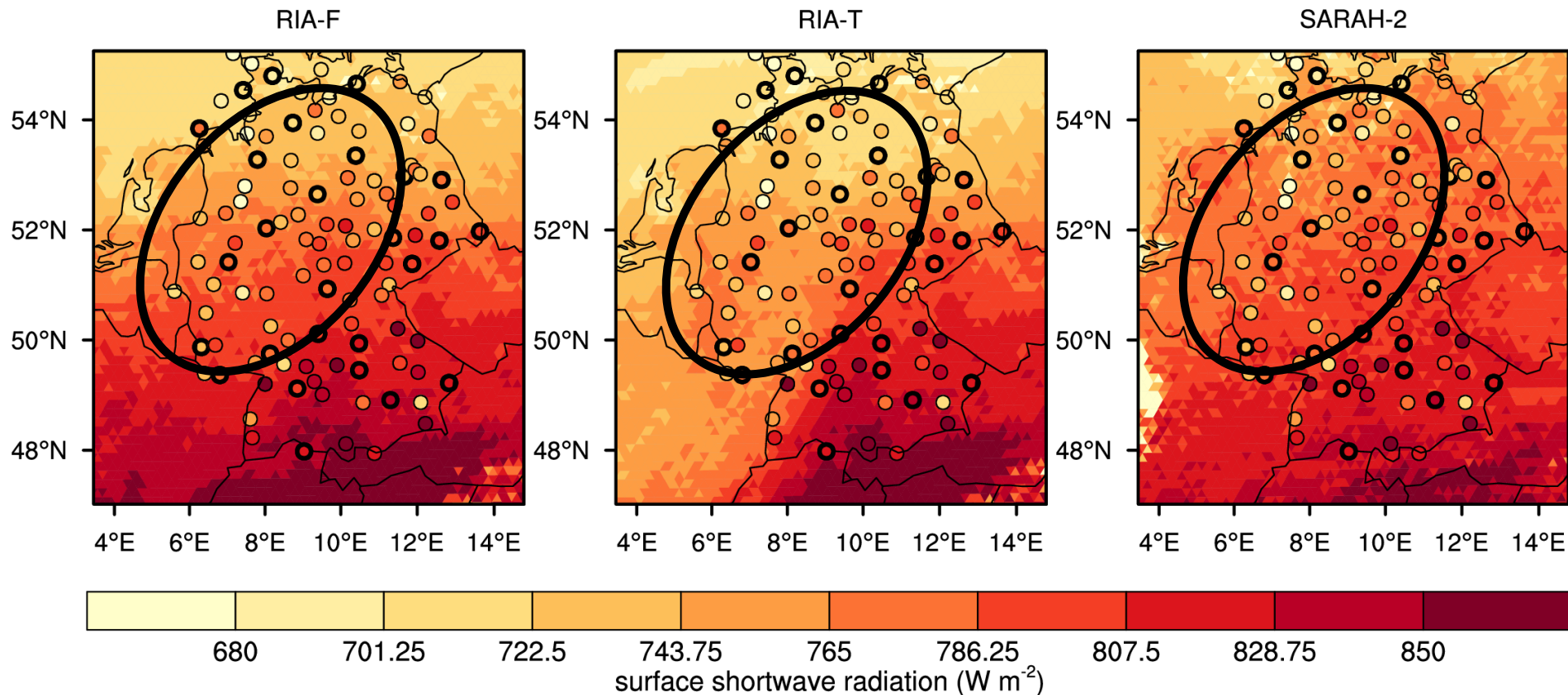
Comparison of global radiation

19 August 2012 11:30 UTC



Comparison of global radiation

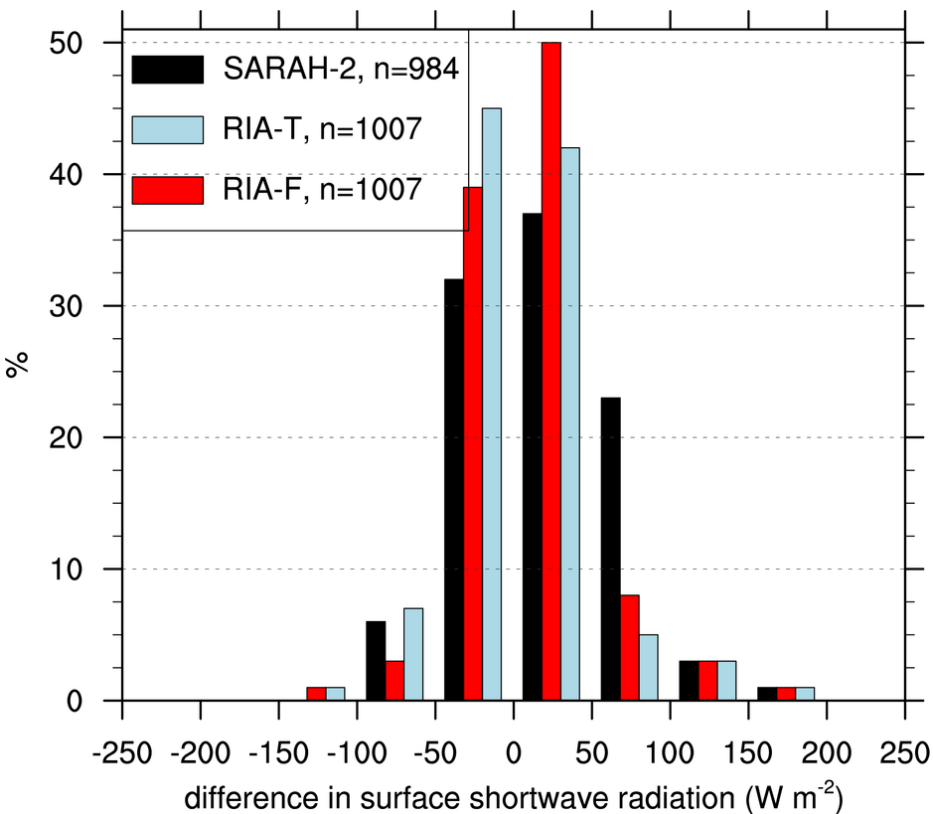
19 August 2012 11:30 UTC



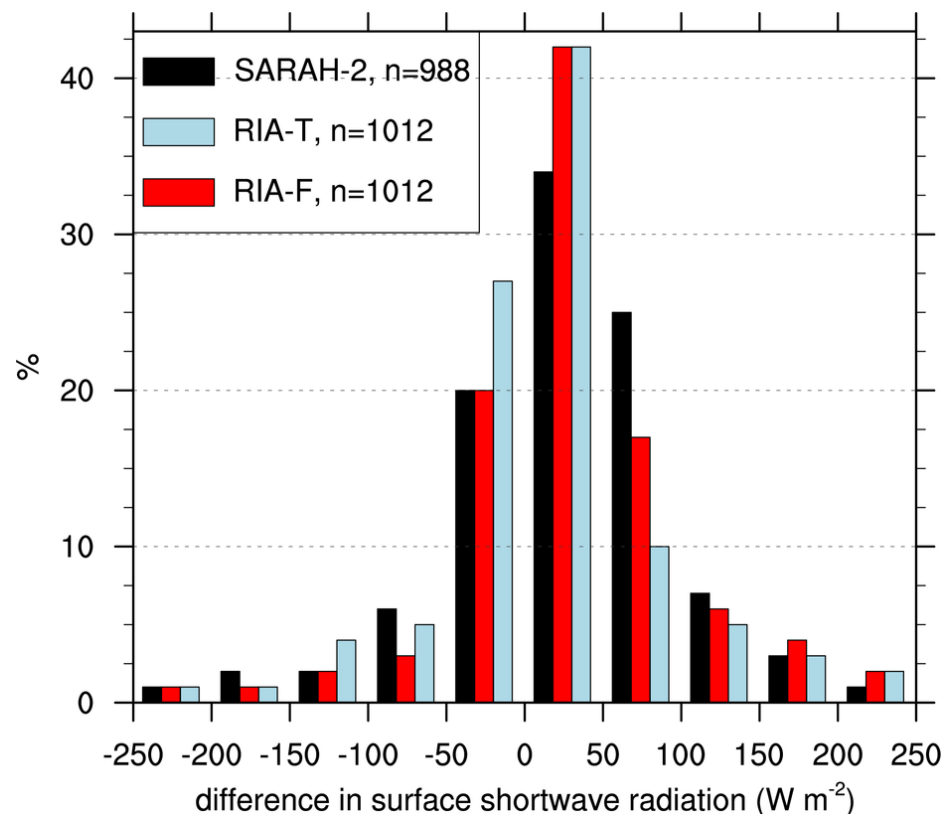
Comparison to synop data

SAT - mae: 38.94, max: 177.17, min: -97.78, rmse: 48.89, stddev: 46.10
 RIA-F - mae: 26.02, max: 167.94, min: -149.19, rmse: 36.87, stddev: 35.58
 RIA-T - mae: 26.09, max: 166.38, min: -133.38, rmse: 36.33, stddev: 36.33

SAT - mae: 64.35, max: 704.33, min: -547.17, rmse: 101.06, stddev: 97.45
 RIA-F - mae: 66.62, max: 605.58, min: -408.09, rmse: 115.38, stddev: 106.92
 RIA-T - mae: 60.15, max: 604.71, min: -376.66, rmse: 110.56, stddev: 106.08



19 August 2012
clear sky



Model/Satellite
minus synop

20 August 2012
partly cloudy sky

- Project PerduS successfully running since 1 year
- Daily mineral dust forecasts with ICON-ART in NUMEX
- Ongoing model improvements and validations
- More Saharan dust outbreaks are welcome

Thank you!

- ➔ 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.
- ➔ 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.