Saharan Dust and Solar Energy Generation in Europe: Case Study of June 2019

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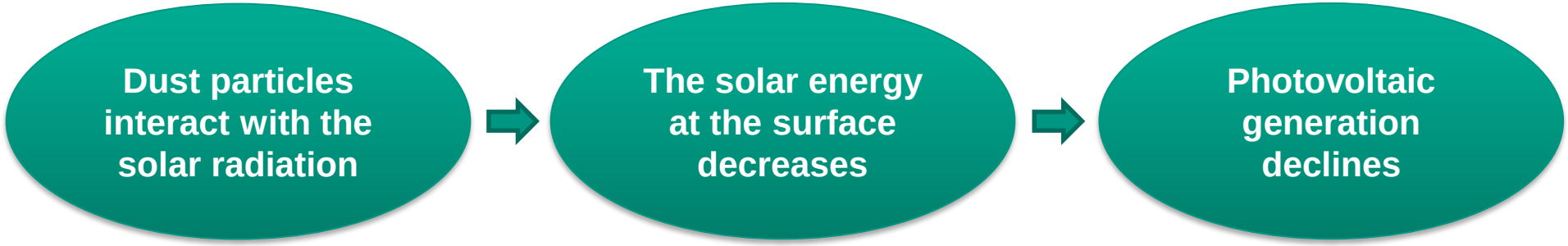
Introduction/Motivation



- Neglecting the dust impact on radiation can lead to overestimation of PV generation in forecast systems.
- Such overestimation in day-ahead forecast of PV generation in Germany cost several million euros annually.
- Quantifying the impact of dust on PV generation is a challenging task because of the interplay of direct, semi-direct and indirect radiative effects.
- In June 2019 a Saharan dust outbreak reached Germany in clear-sky conditions. This was a unique opportunity to quantify the dust direct effect of PV generation.
- Here we present the first result of our investigation on this dust event.

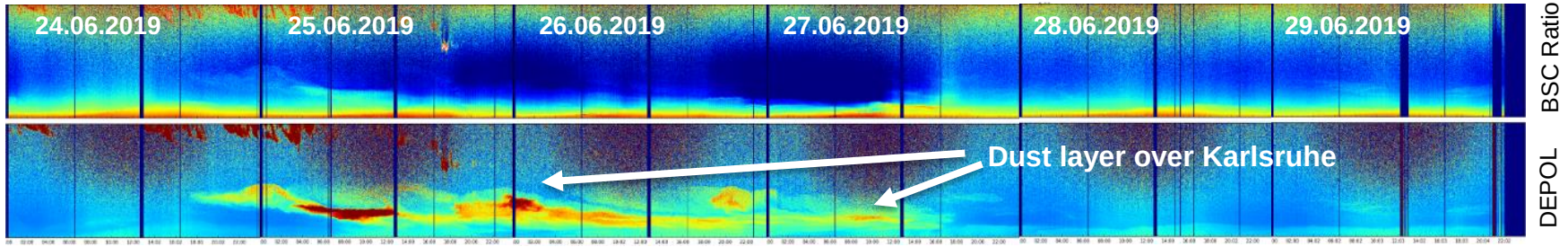
How did the episode in June 2019 look like?

Clear-Sky conditions over most of Germany.

MODIS

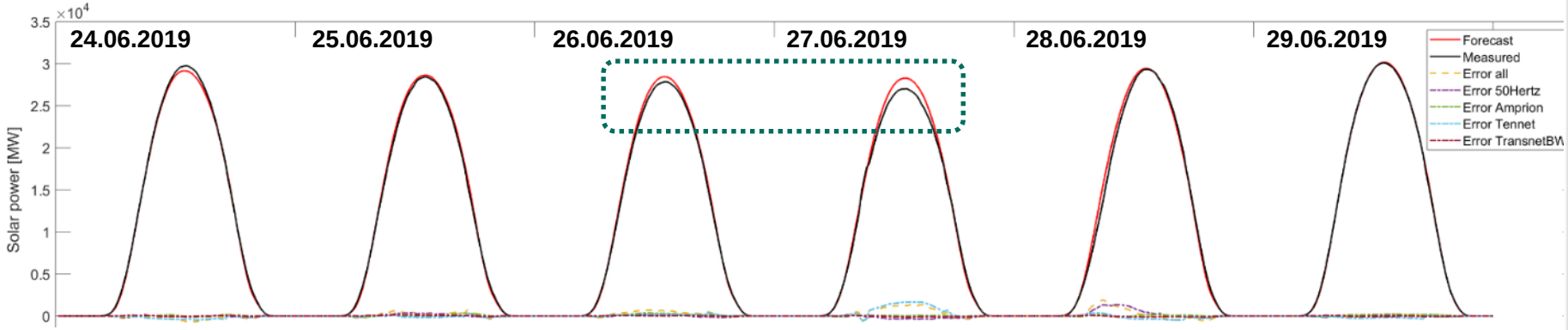
Saharan dust layer over Germany

KIT Lidar



~10% overestimation of PV generation in day-ahead forecast for Germany

DE PV



We use the ICON-ART modeling system

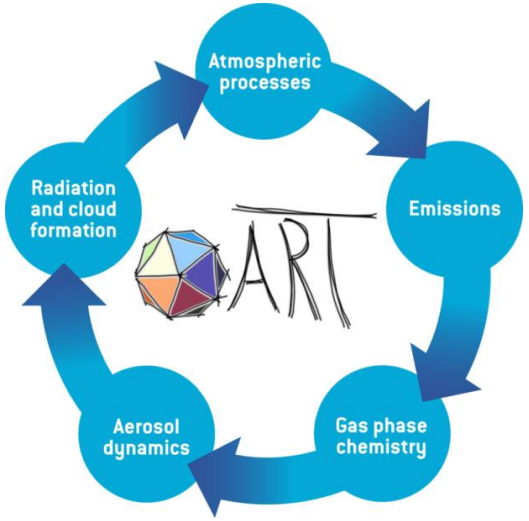
ICON: ICOsahedral Nonhydrostatic

- a unified modeling system for **global** numerical weather prediction and climate studies.

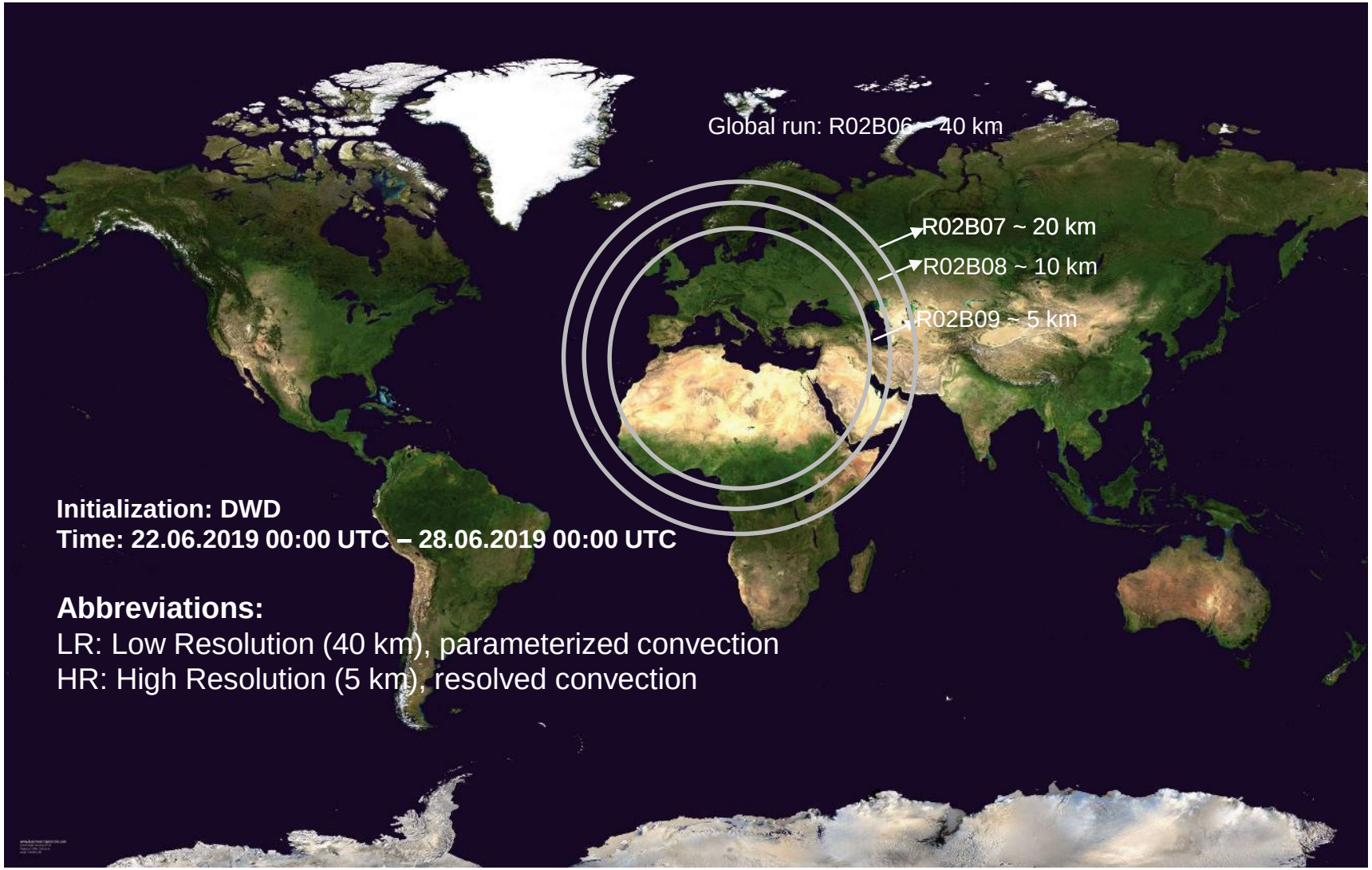
- It has three physics packages:
  - General Circulation Modeling (GCM)
  - Numerical Weather Prediction (NWP)
  - Large Eddy Modeling (LEM)

ART: Aerosols and Reactive Tracers

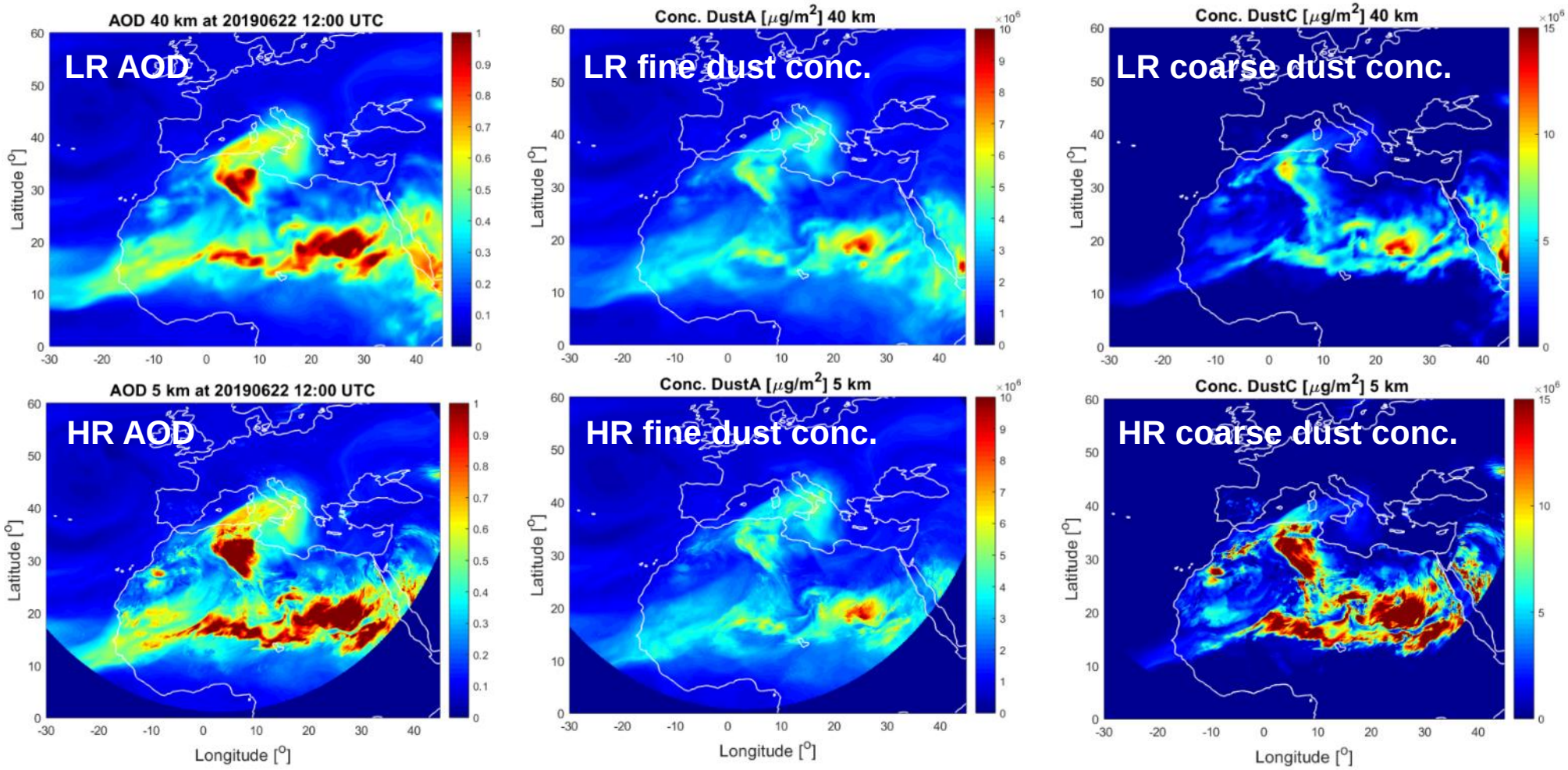
- State-of-the-art aerosol and chemical mechanisms
- Coupling between meteorology and atmospheric composition
- A Flexible interface to implement various mechanism



Simulation set up



AOD and dust column concentration



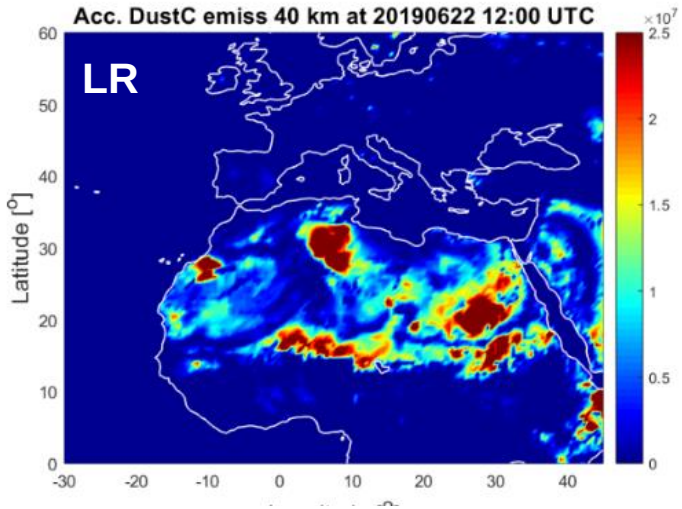
The increased AOD in the HR simulation compared to the LR corresponds to the increased coarse dust loading over the source regions. The loading of the fine mode dust remains almost unchanged.

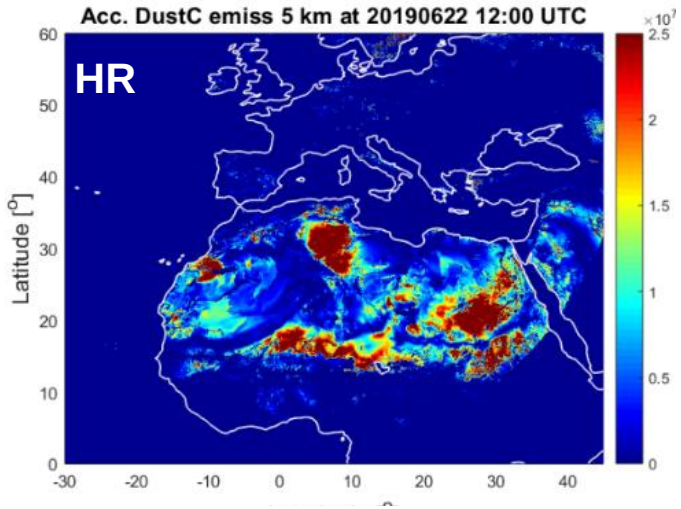
AOD and coarse dust emission

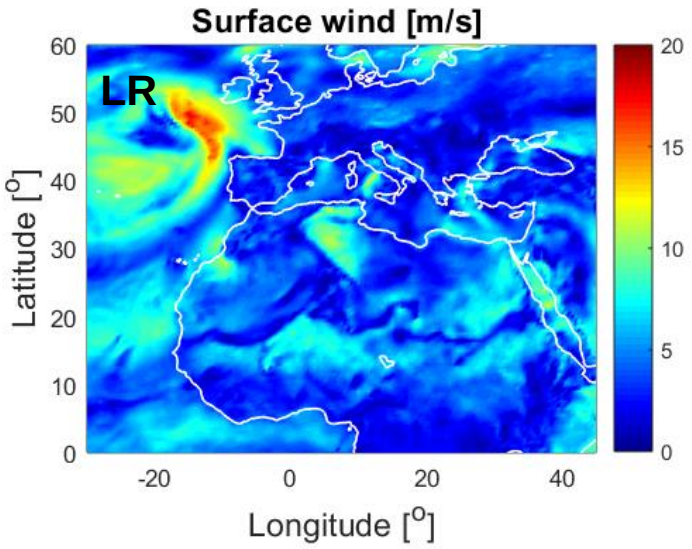
To diagnose the reason for elevated coarse dust loading in the HR simulation, we first look at the accumulated emission of coarse dust.

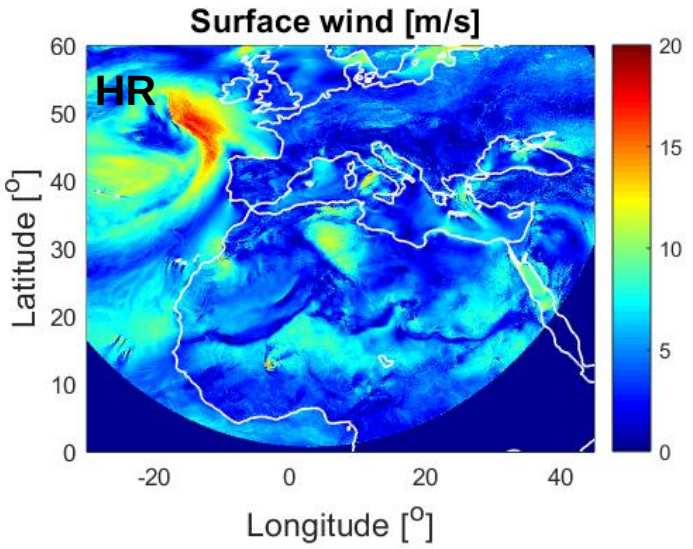
The differences between emissions in two simulations are negligible.

The surface winds are also similar in both simulations.

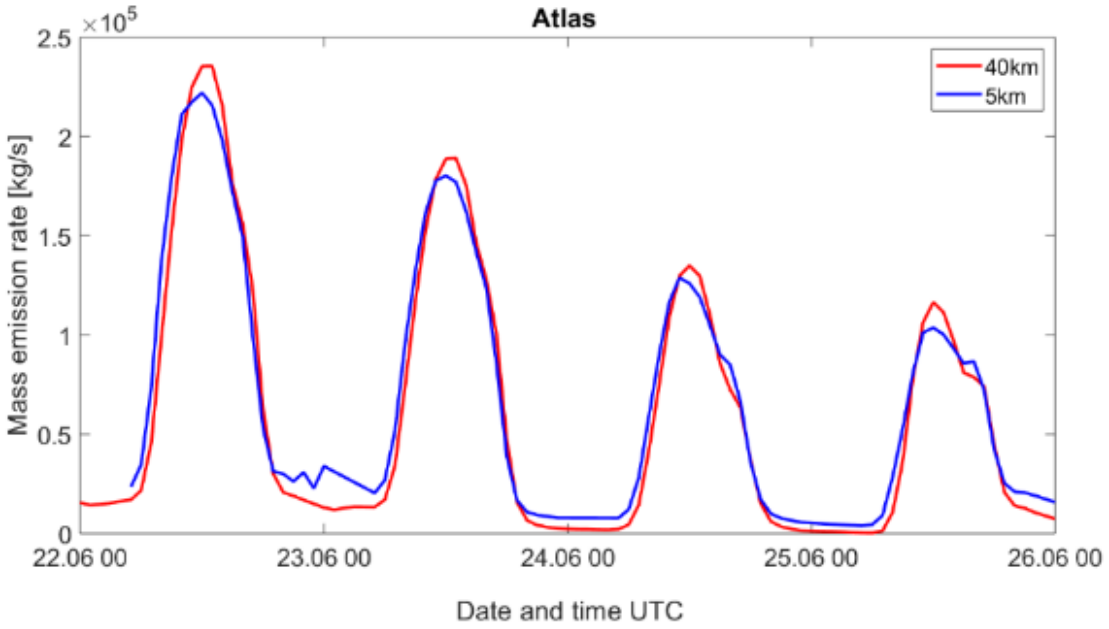


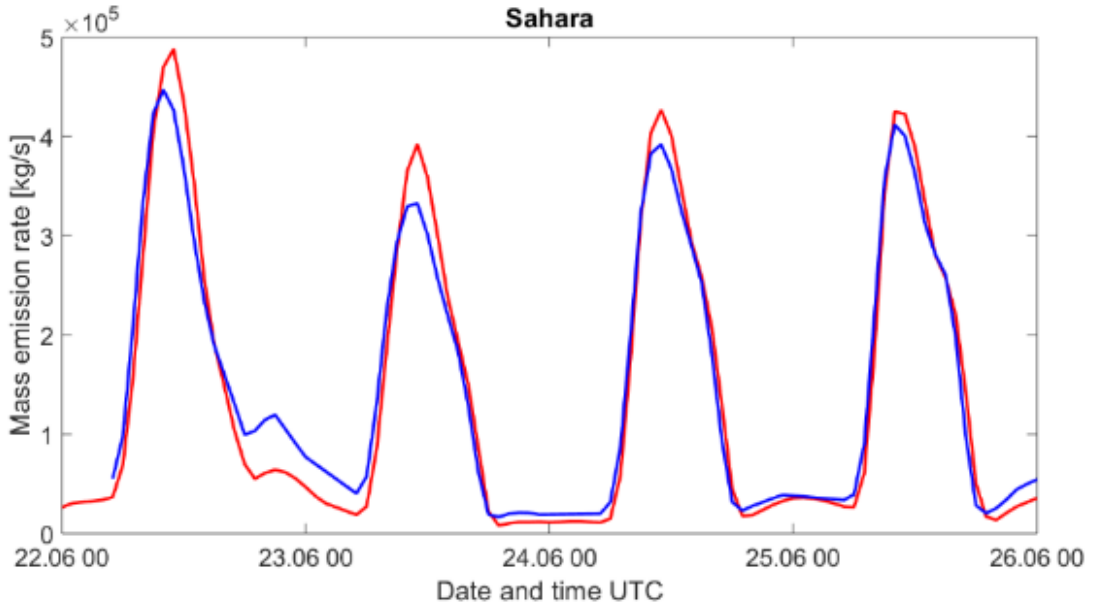






Mass emission rate of coarse dust





We look at the diurnal cycle of emissions in two major dust regions: Atlas mountain and Sahara

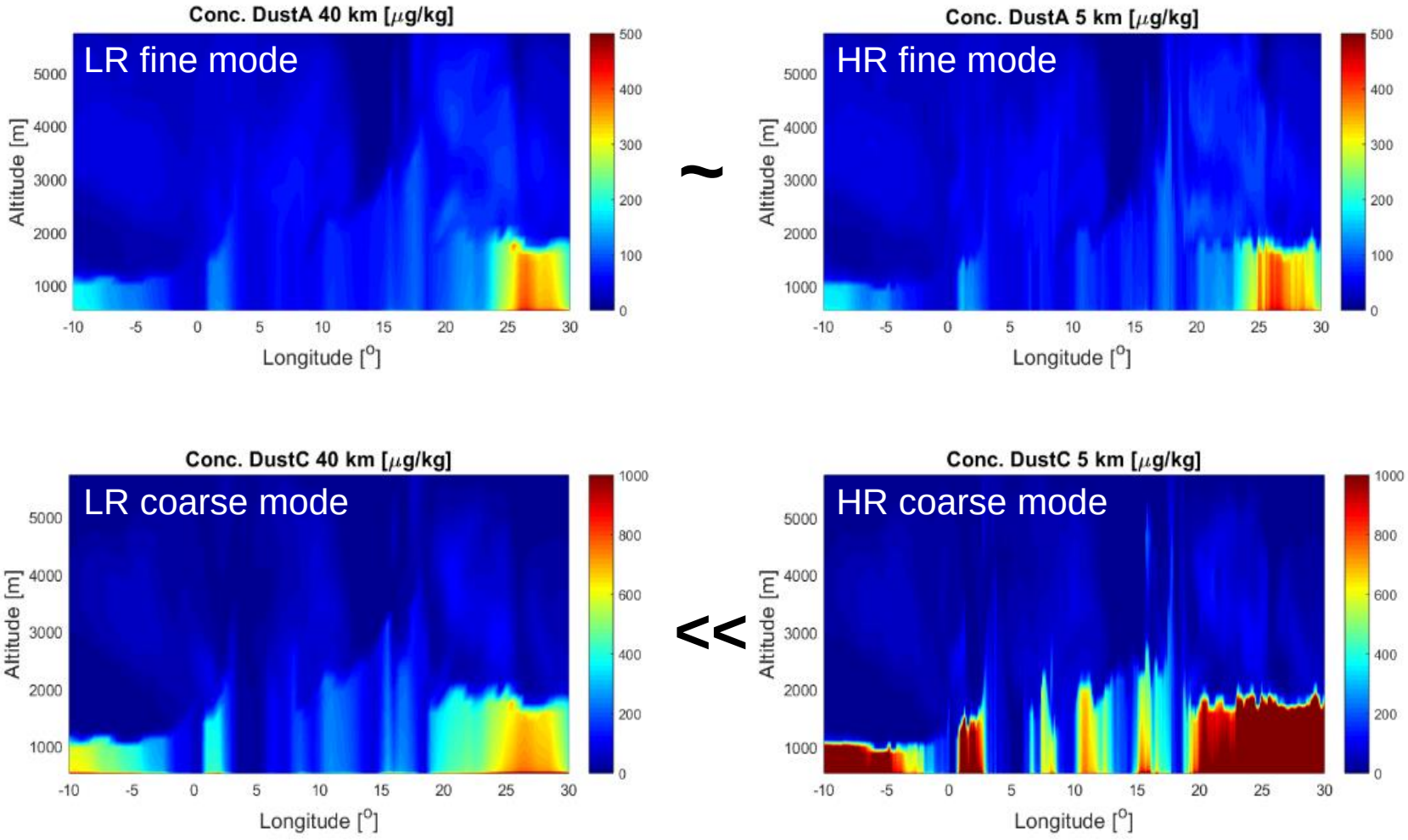
There are some differences between two simulations but overall emissions do not significantly change with resolution.

Vertical profile at 20º N

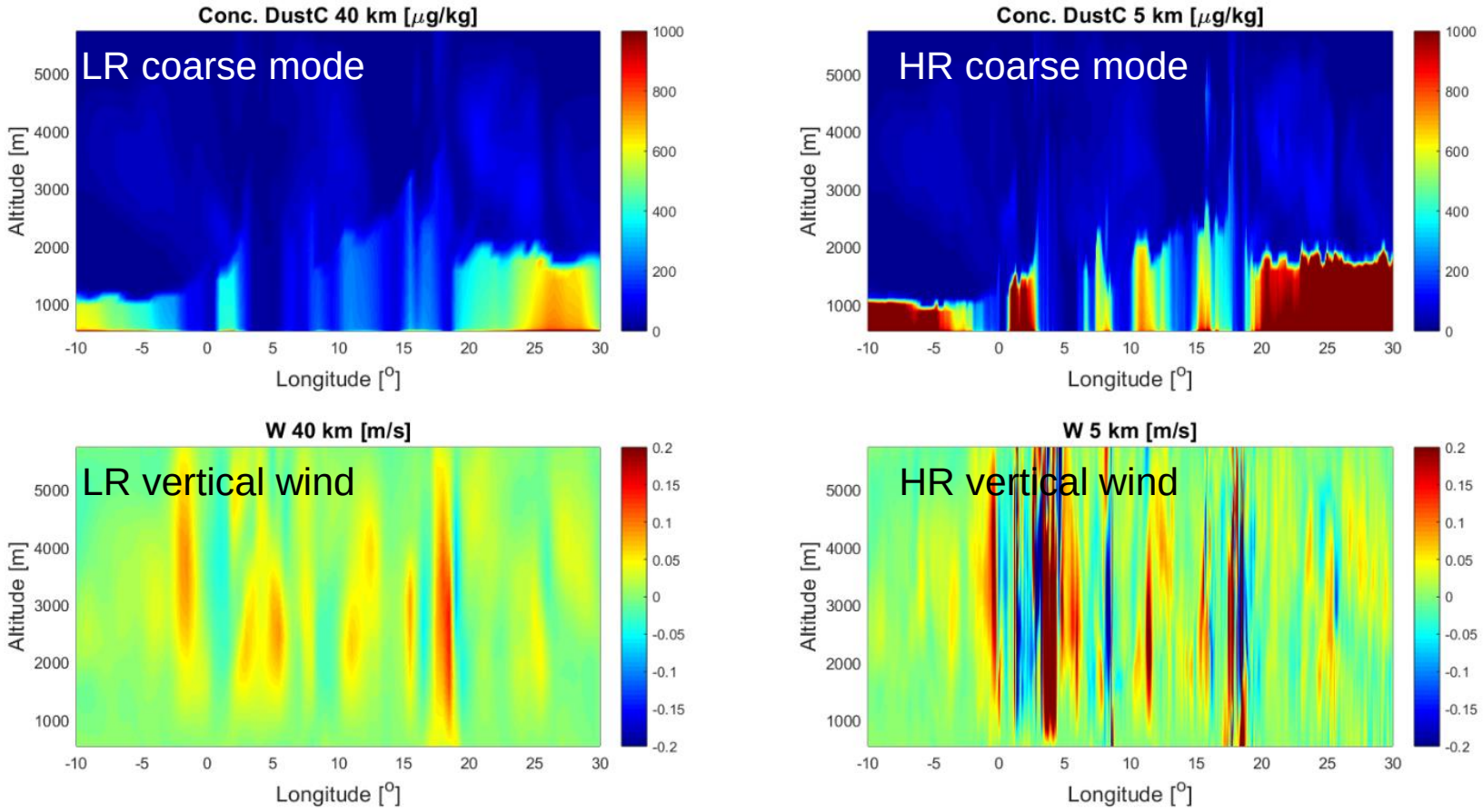
Vertical profiles across the source region in north Africa show that:

1- Fine dust concentration does not change with resolution.

2- Coarse dust concentration increases significantly with resolution.



Vertical profile at 20º N



Vertical profiles across the source region in north Africa confirm that:

Higher vertical velocity → longer life-time in the atmosphere → higher concentrations

Comparison with ceilometer measurements: Mannheim

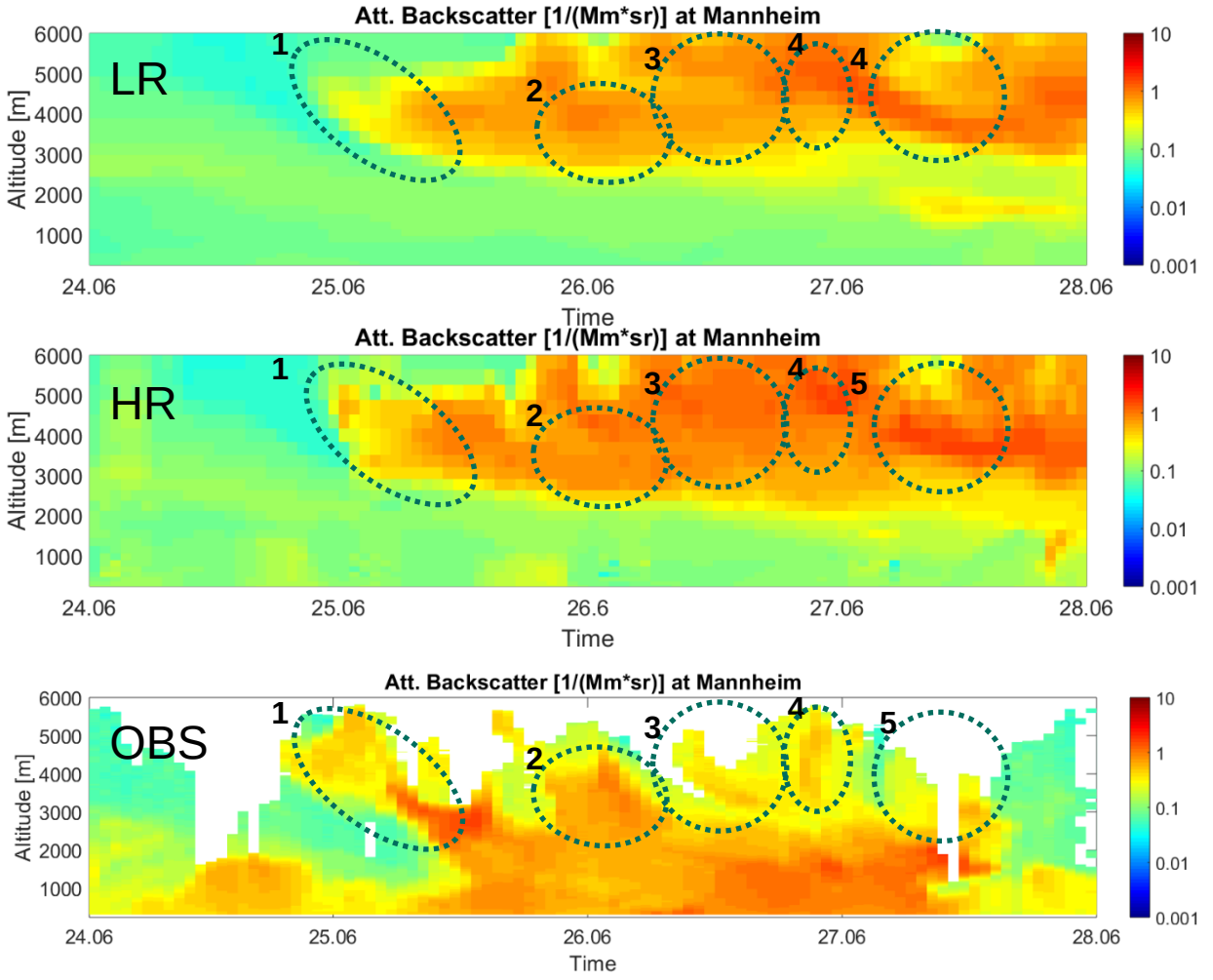
Overall, the signal strength agrees very well with the observation. About the structure:

Oval 1: arrival of the dust layer is better captured in the HR.

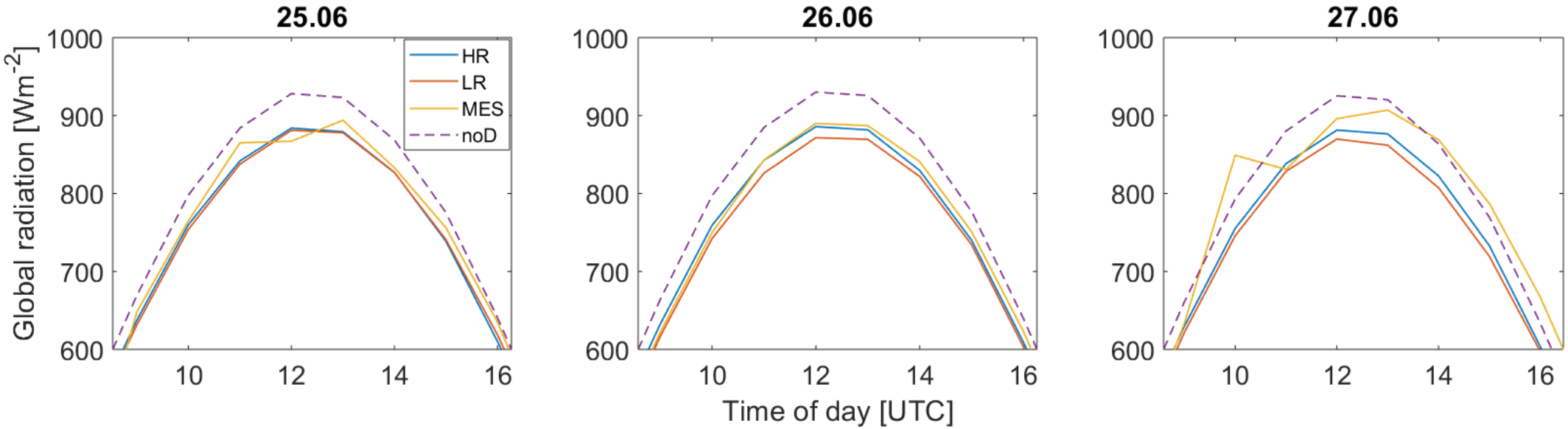
Ovals 2 and 3: The simulated layers are mixed with the upper levels which are not visible to the measurements because of clouds.

Oval 4: The layer in the HR agrees better with the observation

Oval 5: The dust layer sustains until mid day in the observation but in the simulations it remains for the whole day



Comparison with pyranometer measurements: Mannheim

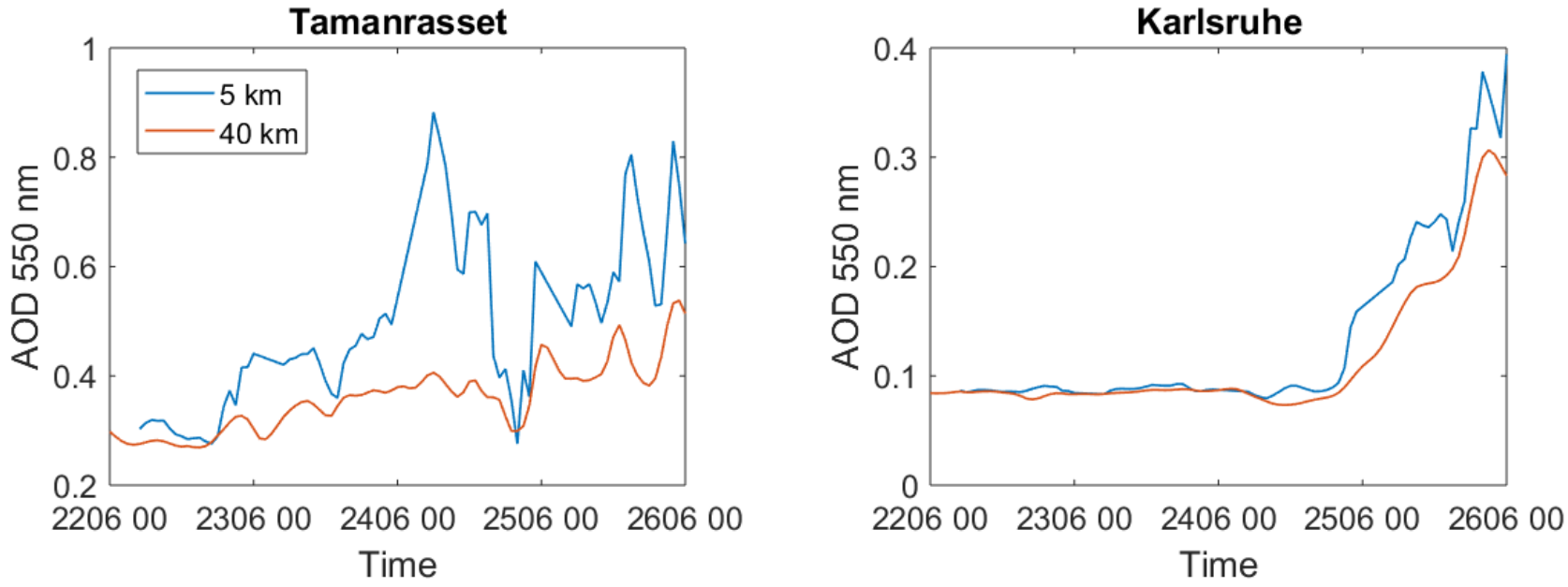


The simulation without dust radiative effect (noD, dashed line) overestimates the measured solar radiation (MES, solid orange line).

The simulations with dust radiative effect (LR and HR) are in very good agreement with the measurements except on 27.06. This might be due to the sustained dust layer in the model (see previous slide).

The HR simulation is slightly better than LR in radiation prediction especially on 26.06 with clear sky.

AERONET stations (without AERONET data yet!)



Significant increase of AOD in the source region (because coarse dust increases).

Slight increase of AOD in Germany and Europe (because fine dust remains almost unchanged).

Summary and outlook

- Convection-resolving simulations lead to prolonged life-time of the coarse particles and thus, higher dust loading and AOD in source regions.
- The effect on transported dust (fine mode) is not significant (at least in short-term).
- Taking dust direct radiative effect into account can reduce the error in global radiation prediction by up to 50%.
- Convection-resolving simulations better predict the vertical distribution of dust but only slightly improve the radiation forecast over Germany.
- Verification is ongoing for other ceilometer, pyranometer and AERONET stations.