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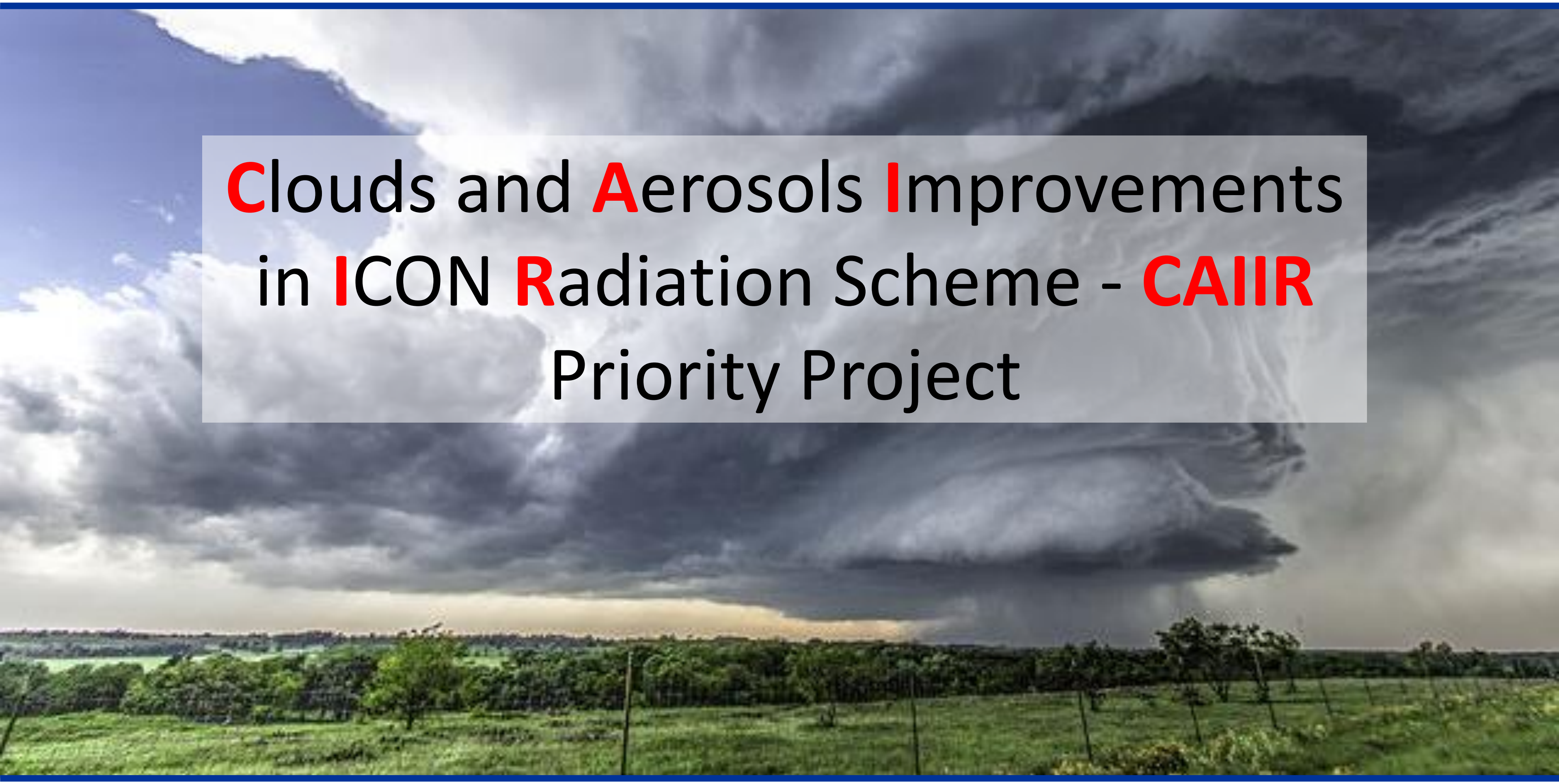
CONSORTIUM FOR SMALL SCALE MODELING COSMO

Clouds and Aerosols Improvements in ICON Radiation Scheme - CAIIR Priority Project



Harel Muskatel (IMS)

23nd COSMO General Meeting, September 14, 2021

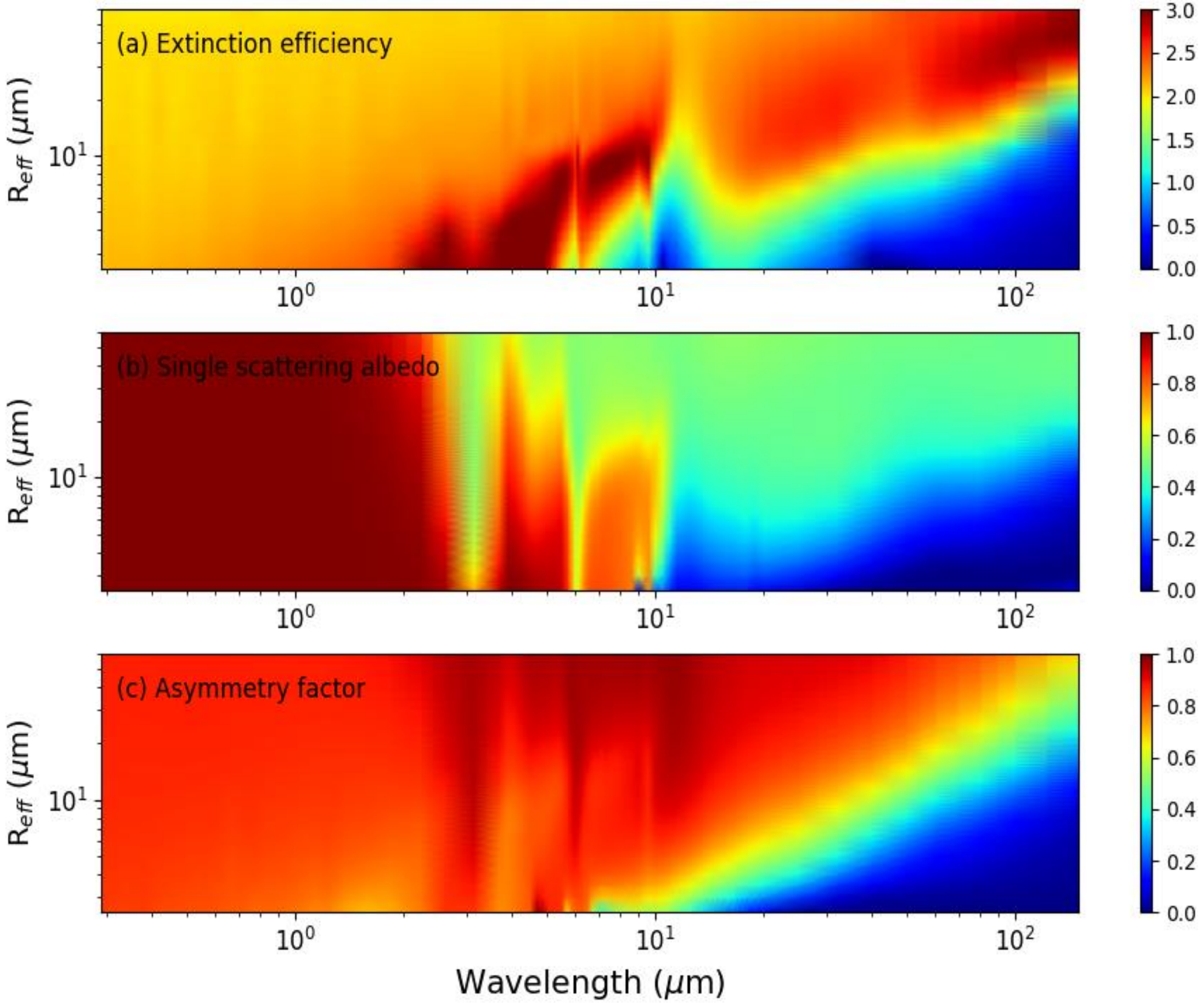
Clouds and Aerosols Improvements in ICON Radiation Scheme - CAIIR Priority Project

- **Project duration: March 2020 - February 2022**
- **Total planed FTEs : 6.6 (2.9, 3.7)**
- **Used until Sep-2021: 4.57**

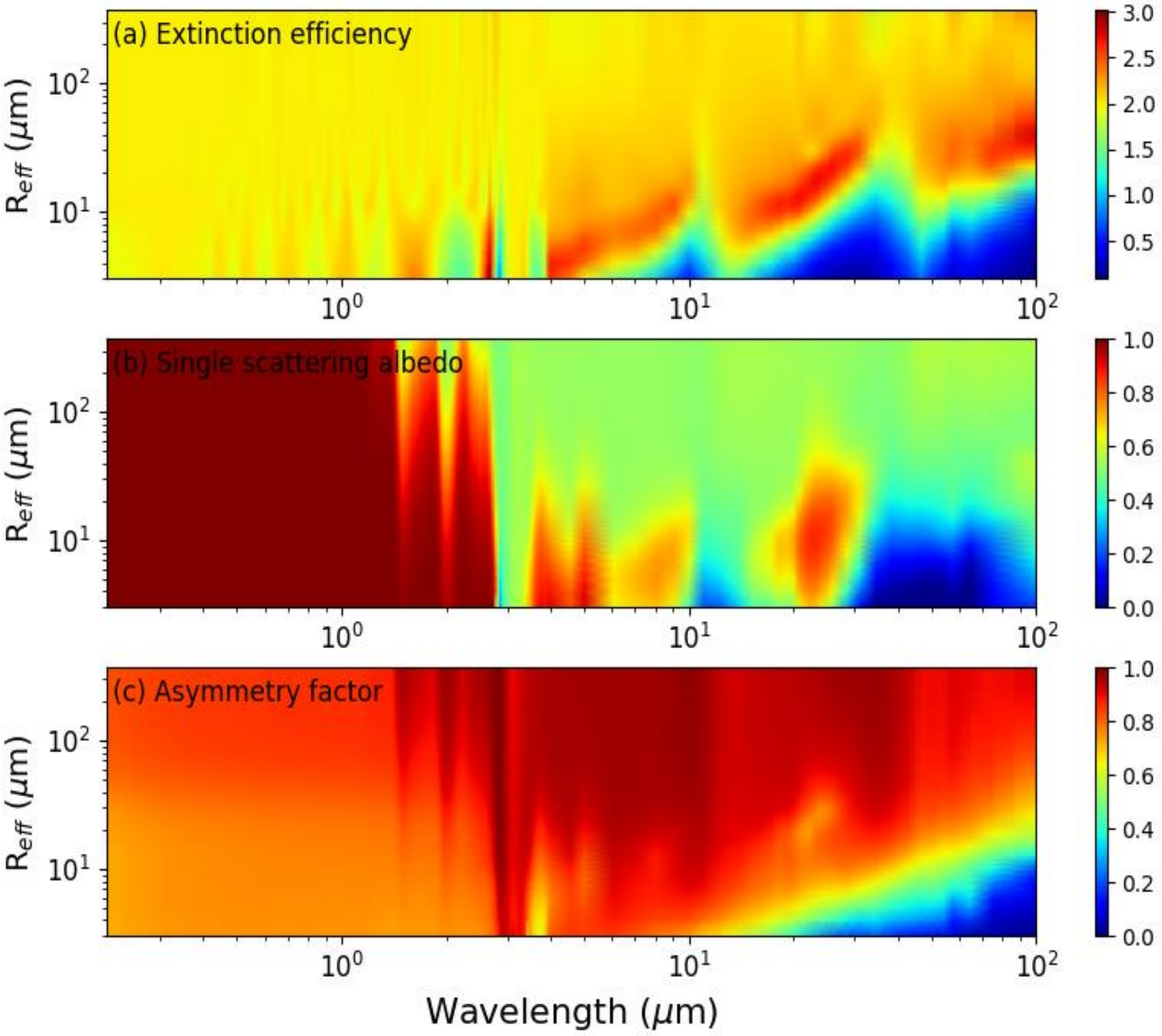
Participants:

- Harel Muskatel (IMS)
- Pavel Khain (IMS)
- Alon Shtivelman (IMS)
- Yoav Levi (IMS)
- Ulrich Blahak (DWD)
- Daniel Rieger (DWD)
- Alexey Poliukhov (RHM)
- Julia Khlestova (RHM)
- Gdaly Rivin (RHM)
- Natalia Chubarova (RHM)
- Marina Shatunova (RHM)

Task 1: New droplets optical properties for ecRAD

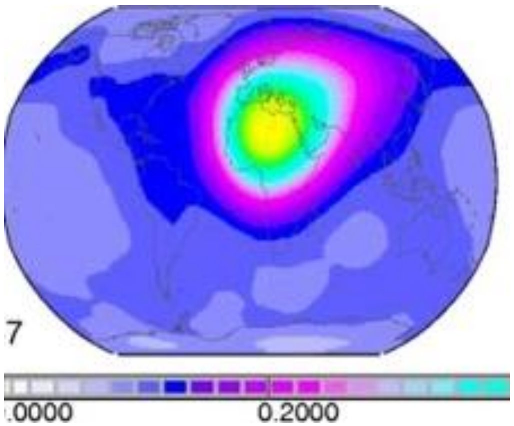


Task 2: New ice optical properties for ecRAD

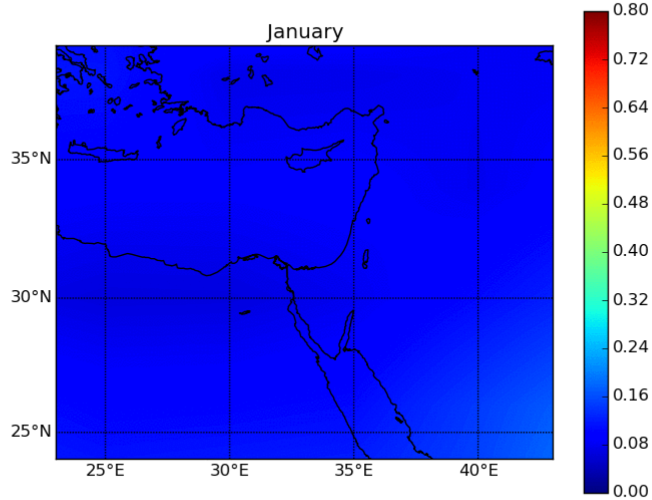


Aerosols Inputs for ICON Radiation

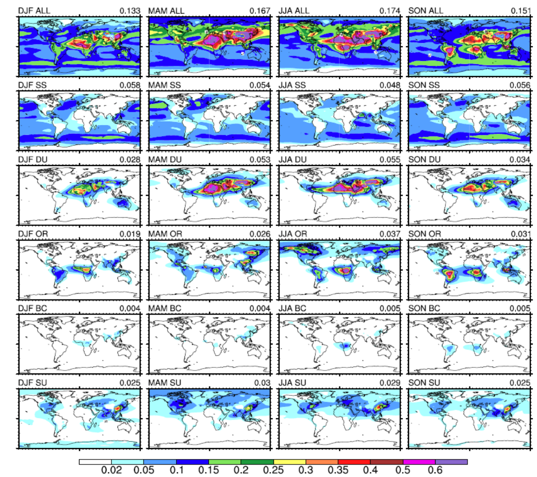
Tanre (1983)
irad_aero = 5



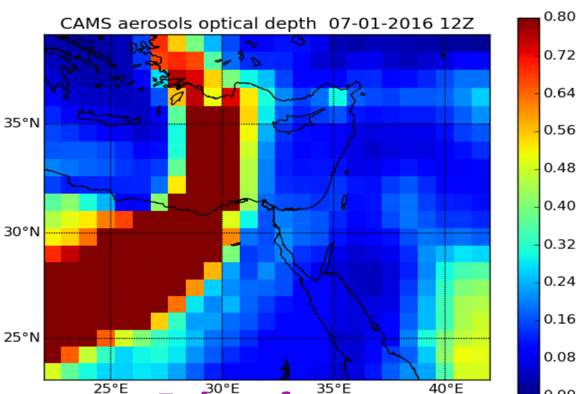
Tegen (1997)
irad_aero = 6



CAMS (2017)
irad_aero = 7

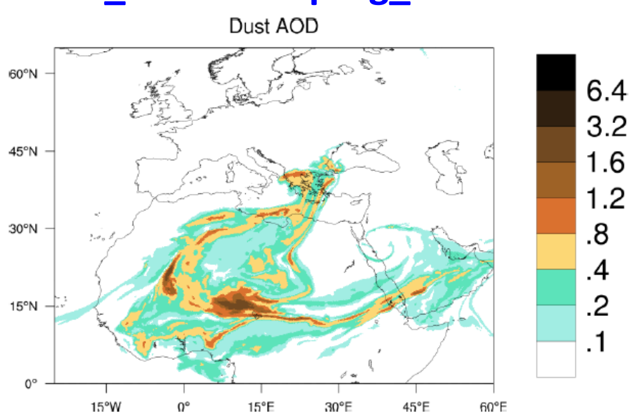


CAMS
irad_aero = 8

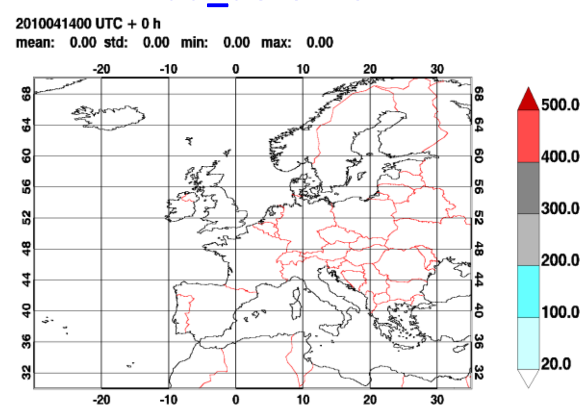


5 days forecast

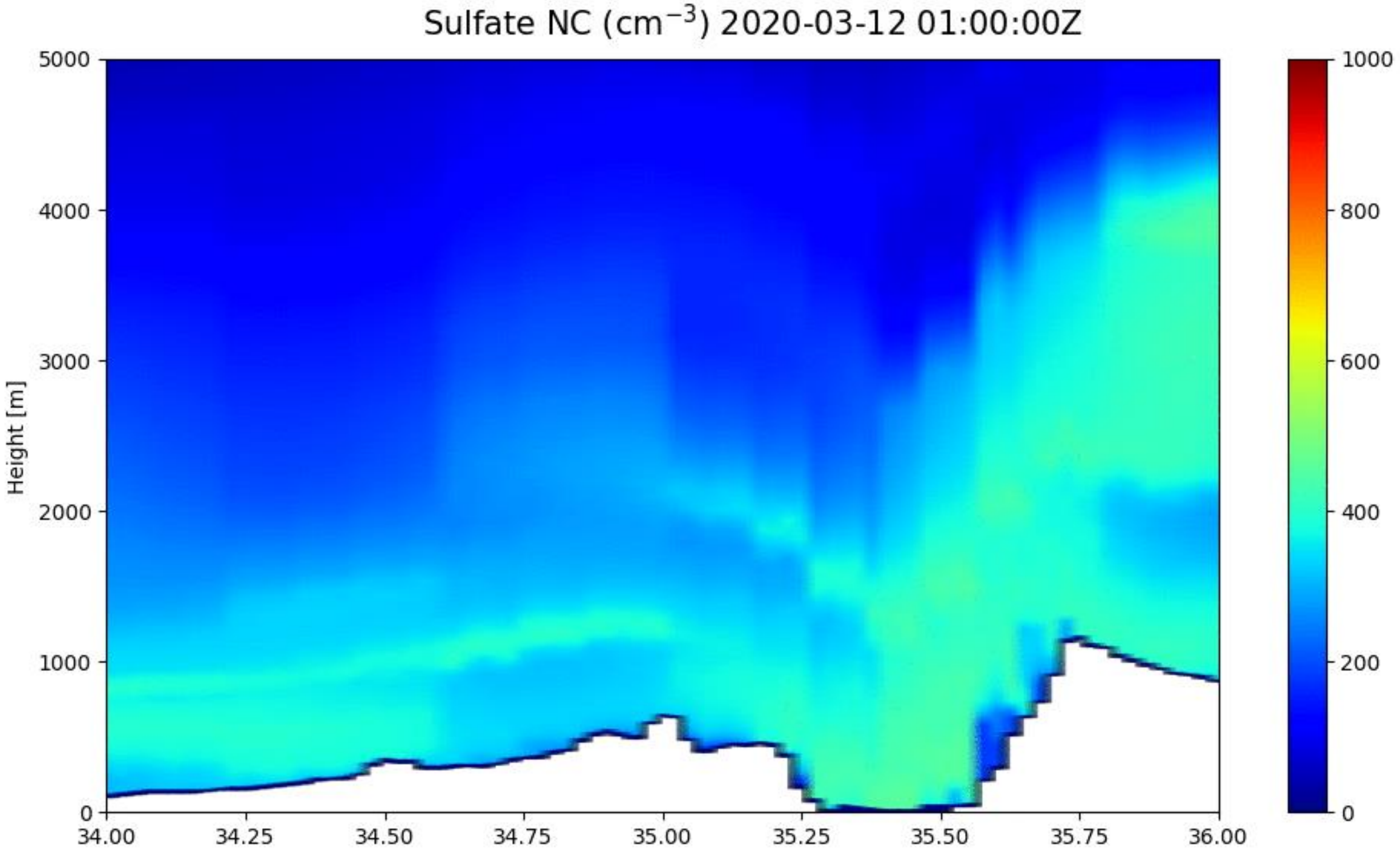
Prognostic 2D AOD
irad_aero=6 & iprog_aero=1



ICON-ART
irad_aero = 9



Task 4: CAMS forecasted aerosols in ICON



Advantages of CAMS forecasted aerosols

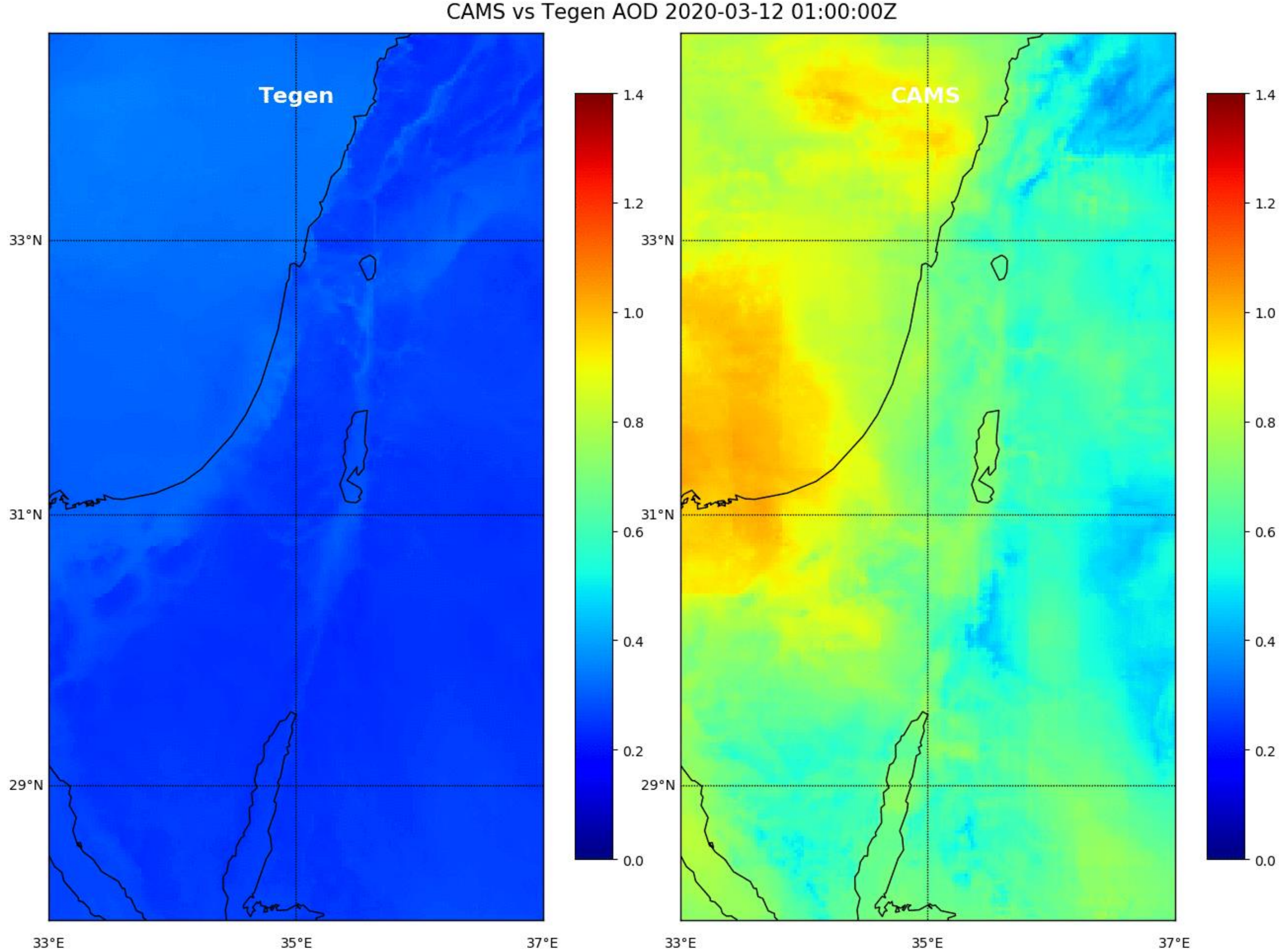
CAMS	Climatology
Vertical profile based on dynamics	Fixed vertical profile
Optical properties calculated for each RRTM/ecRad WL intervals	Optical properties calculated at 550 nm and corrections made for other WL
Optical properties are RH dependent	Optical properties RH independent
Number concentrations are calculated explicitly from mixing ratios	Number concentrations are evaluated from total column AOD
11 species of aerosols	5 species of aerosols
Data assimilation used	Fixed climatology
Longwave scattering included	No longwave scattering

With almost zero additional CPU cost

Additional memory is needed

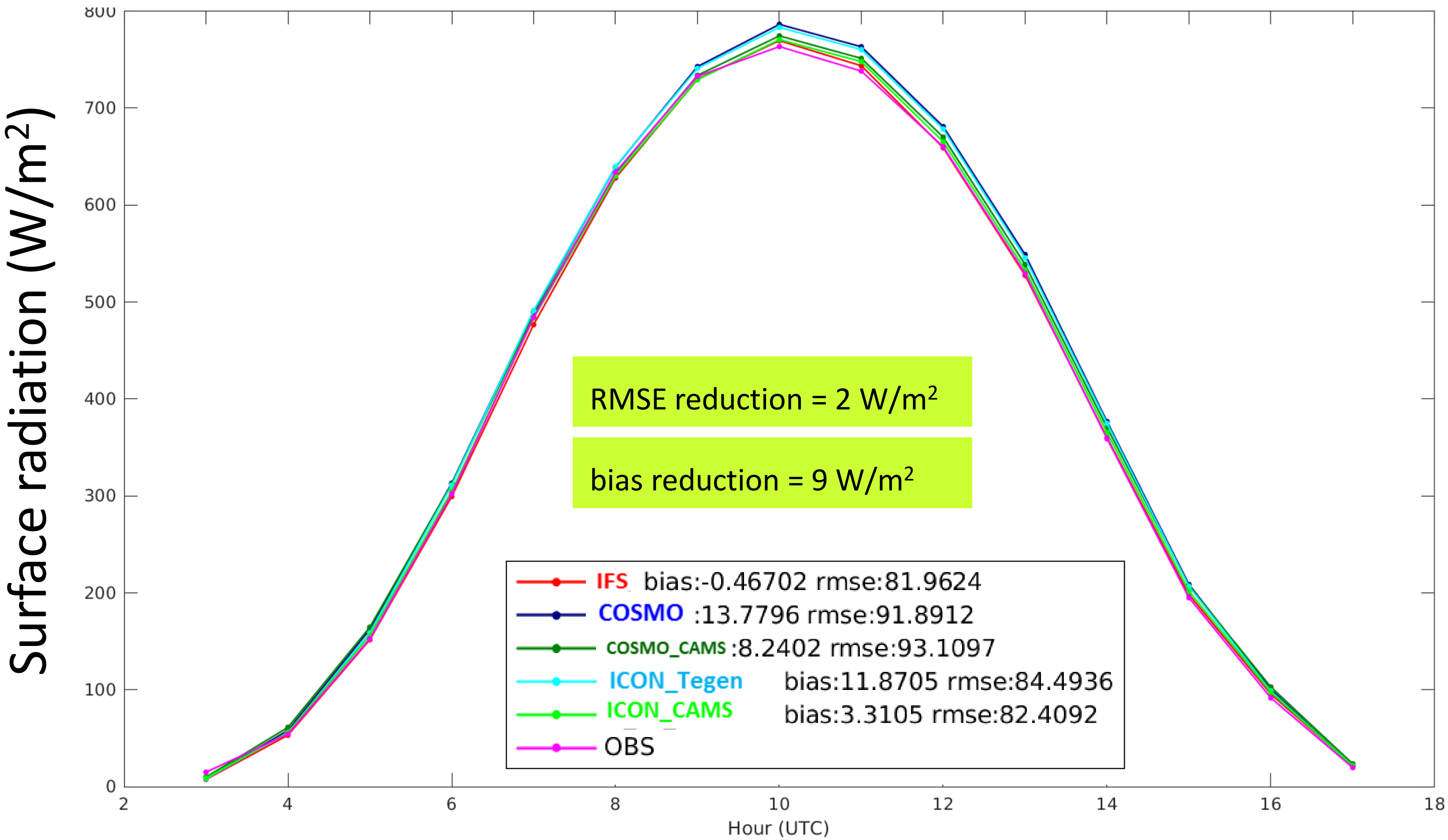
Dynamics, emissions, washout etc. are done in a separate model not consistent/coupled with ICON model

2D integrated AOD



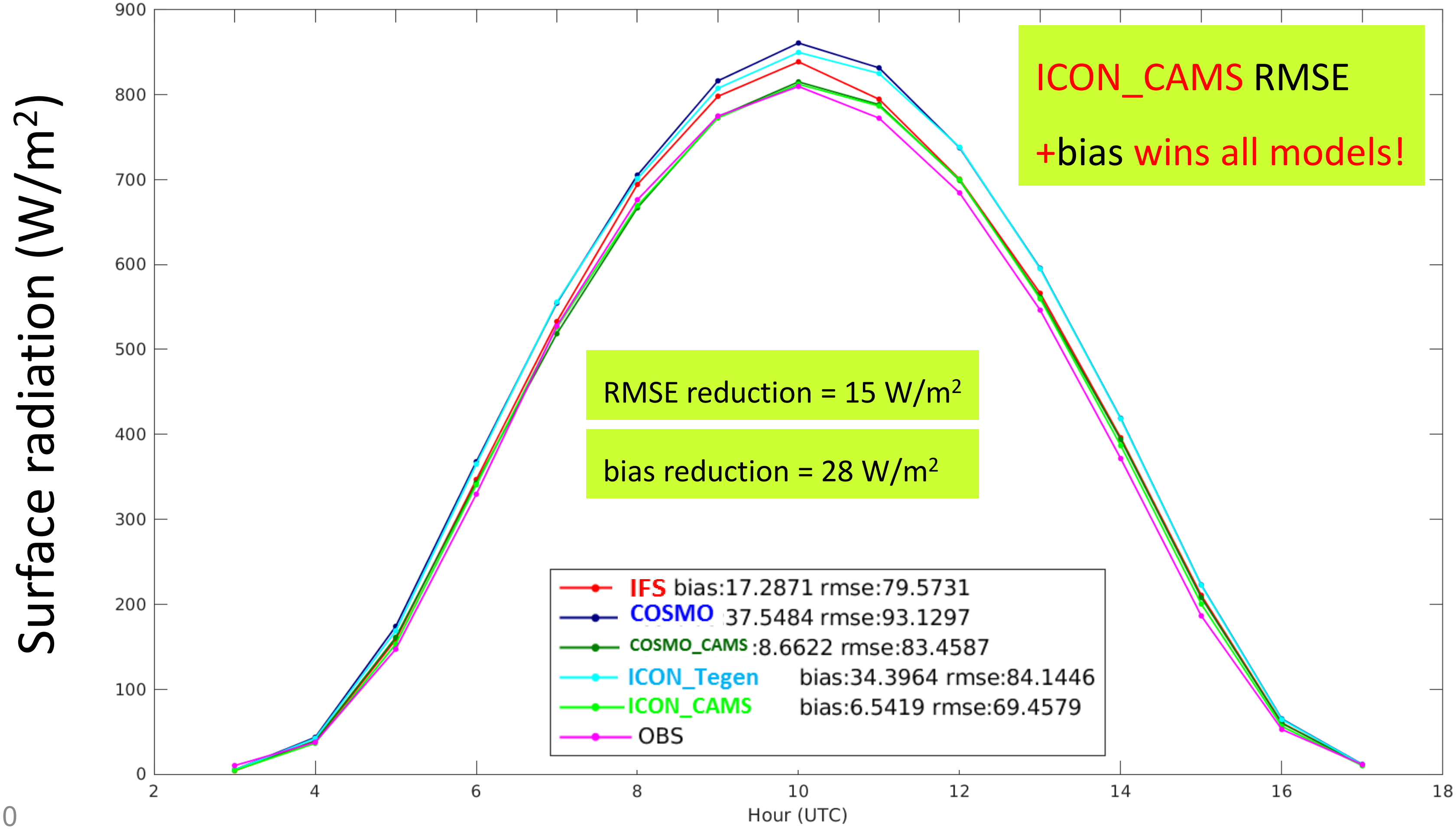
1 Year Verifications – 2020

- 2020, 78 hours lead time, 00UTC RUNS

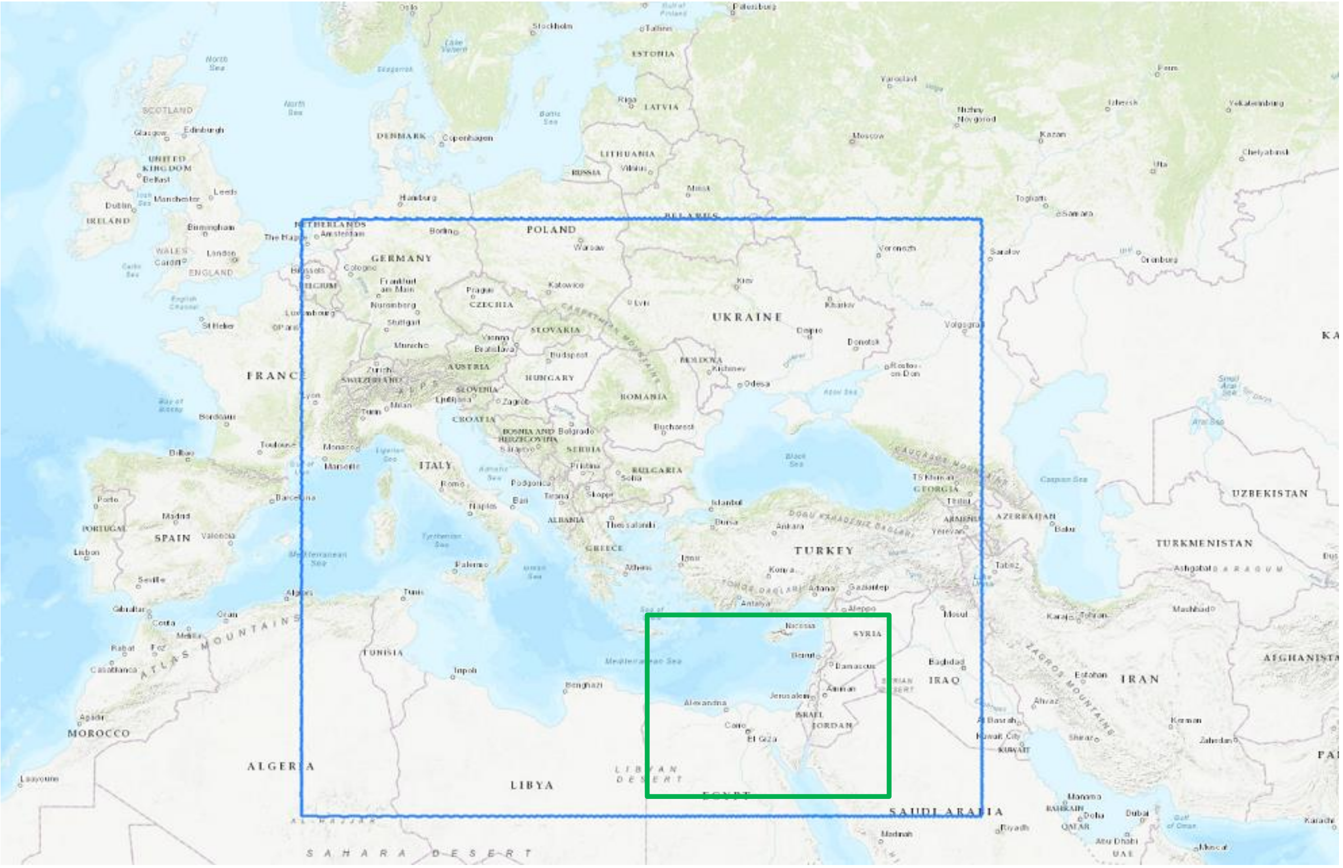


Verifications – polluted days

- 28 test cases in 2020, 24 hours lead time
- When average measurements of PM2.5 all over Israel is more than x2 greater than annual average

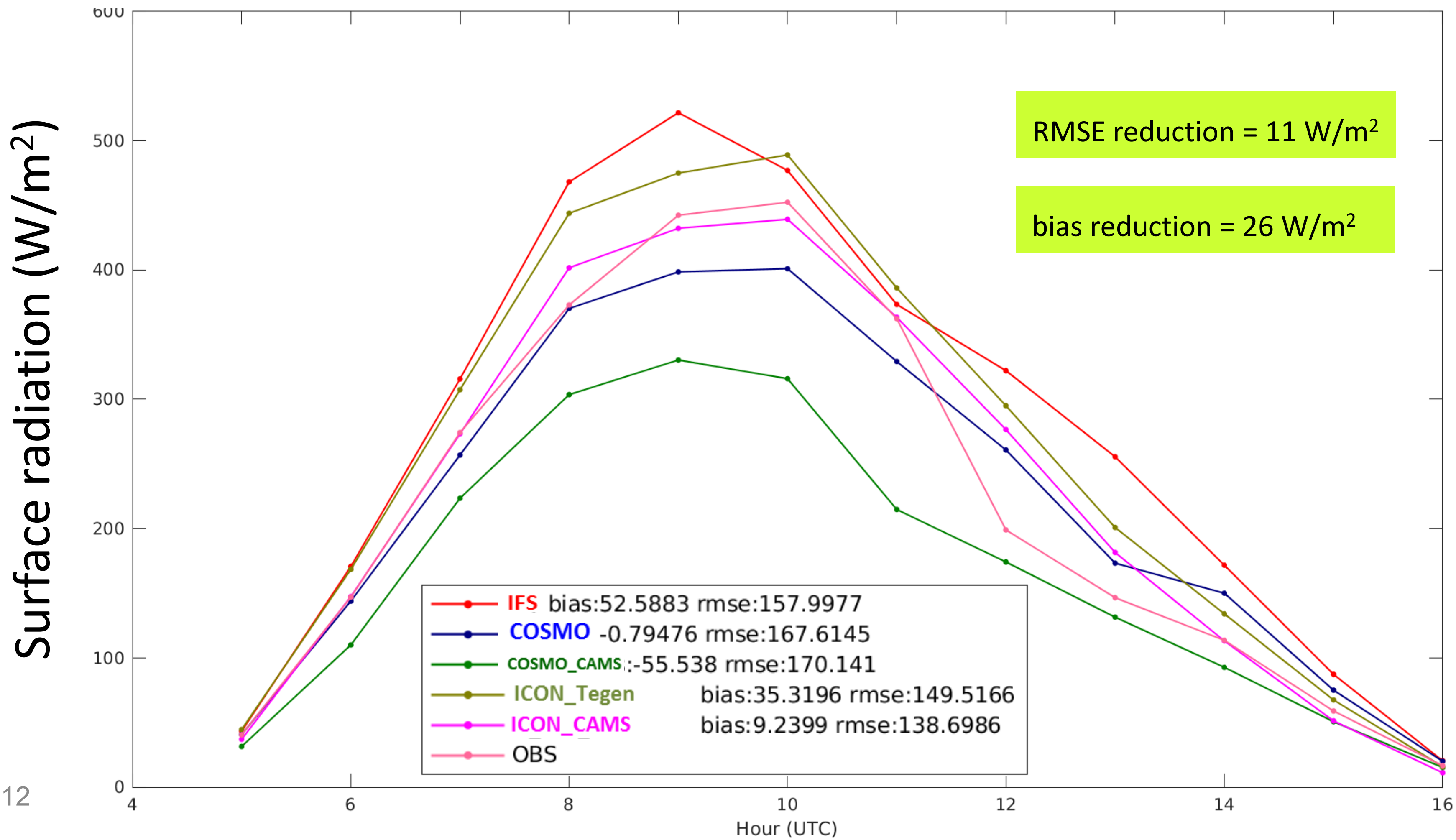


Southeast Europe Domain

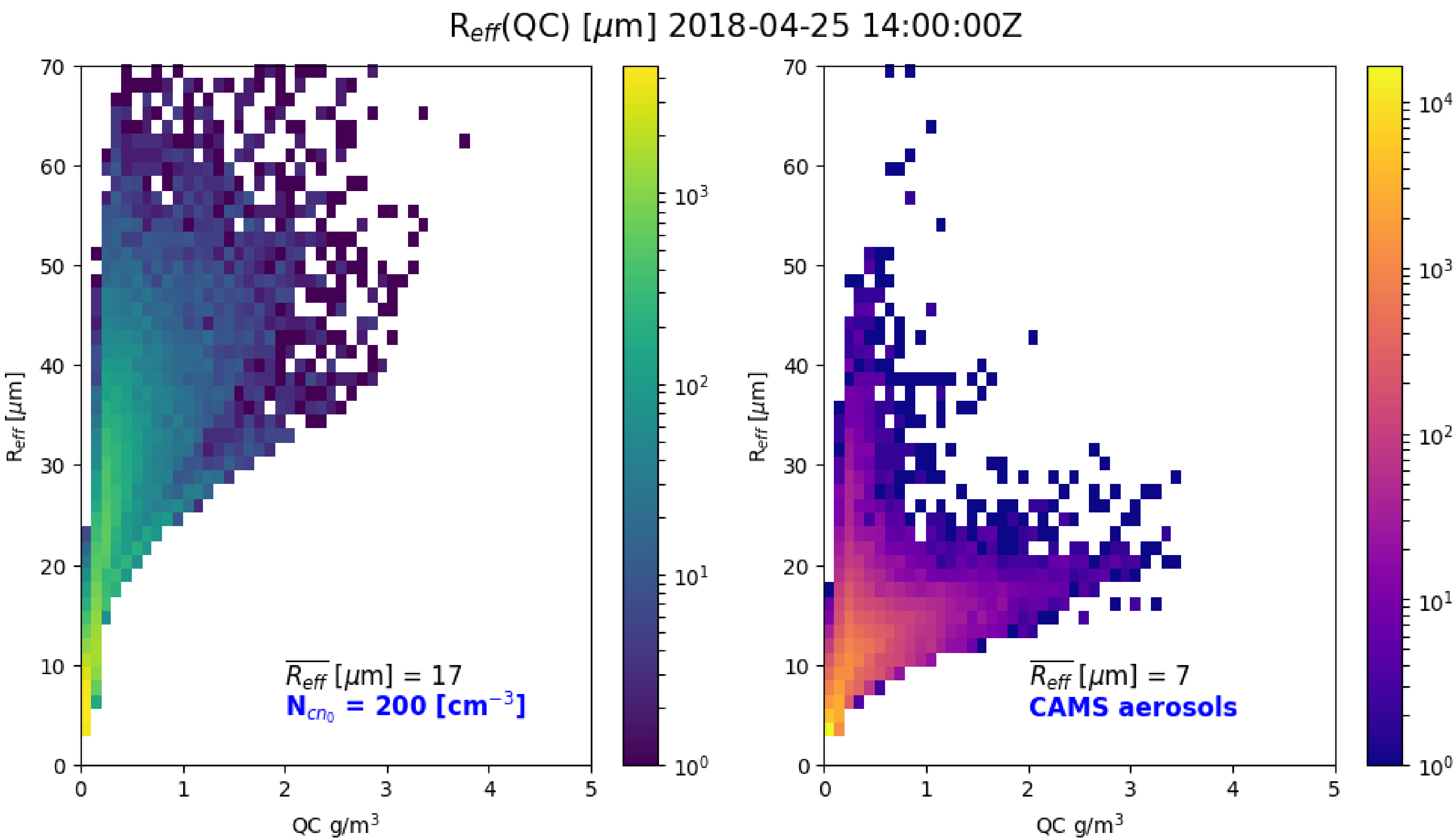


12 March 2020 test case

- 78 hours lead time, 00UTC RUN
- Verifications in Israel only

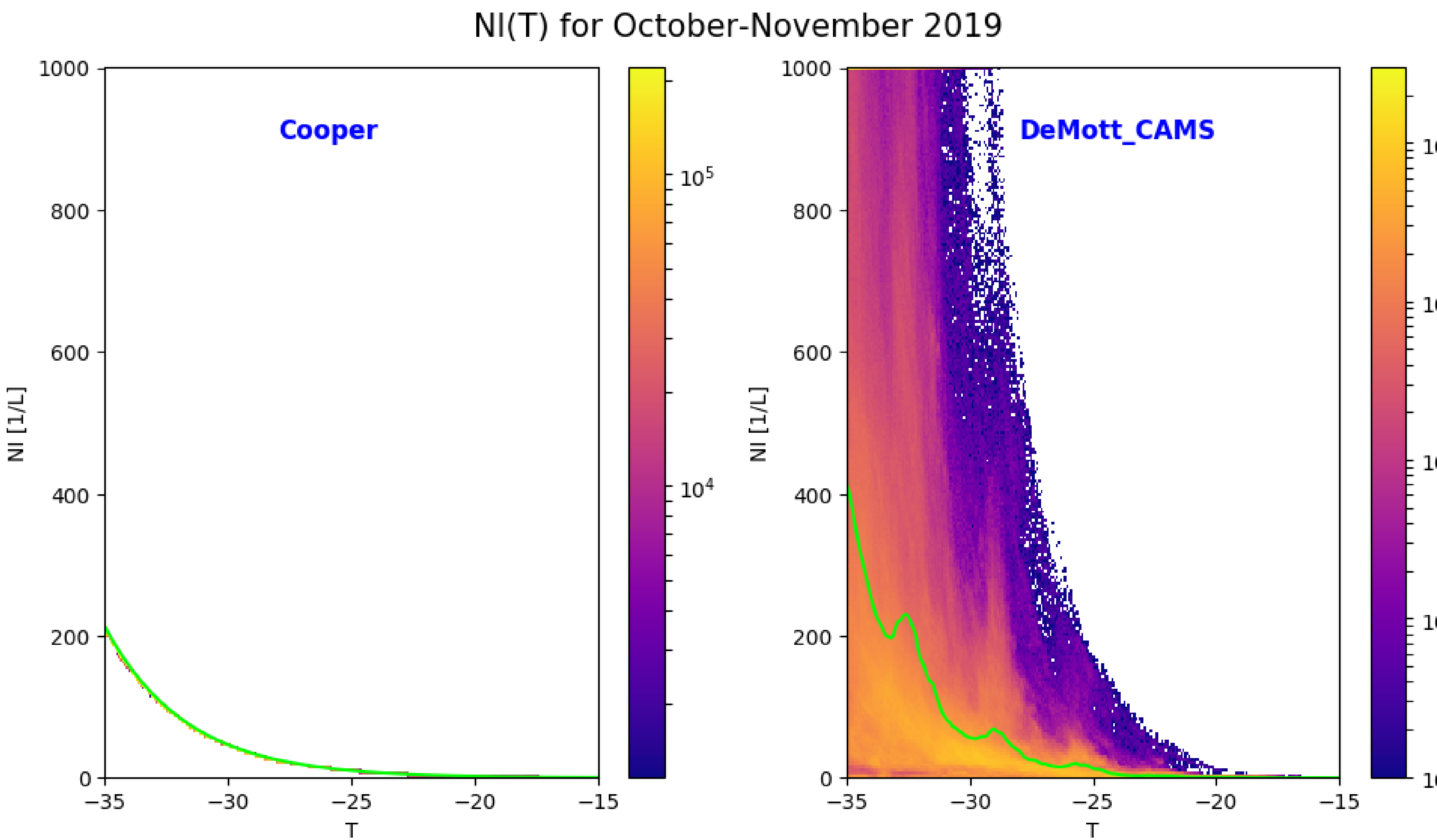


Task 3: R_{eff} based on CAMS & Segal-Khain

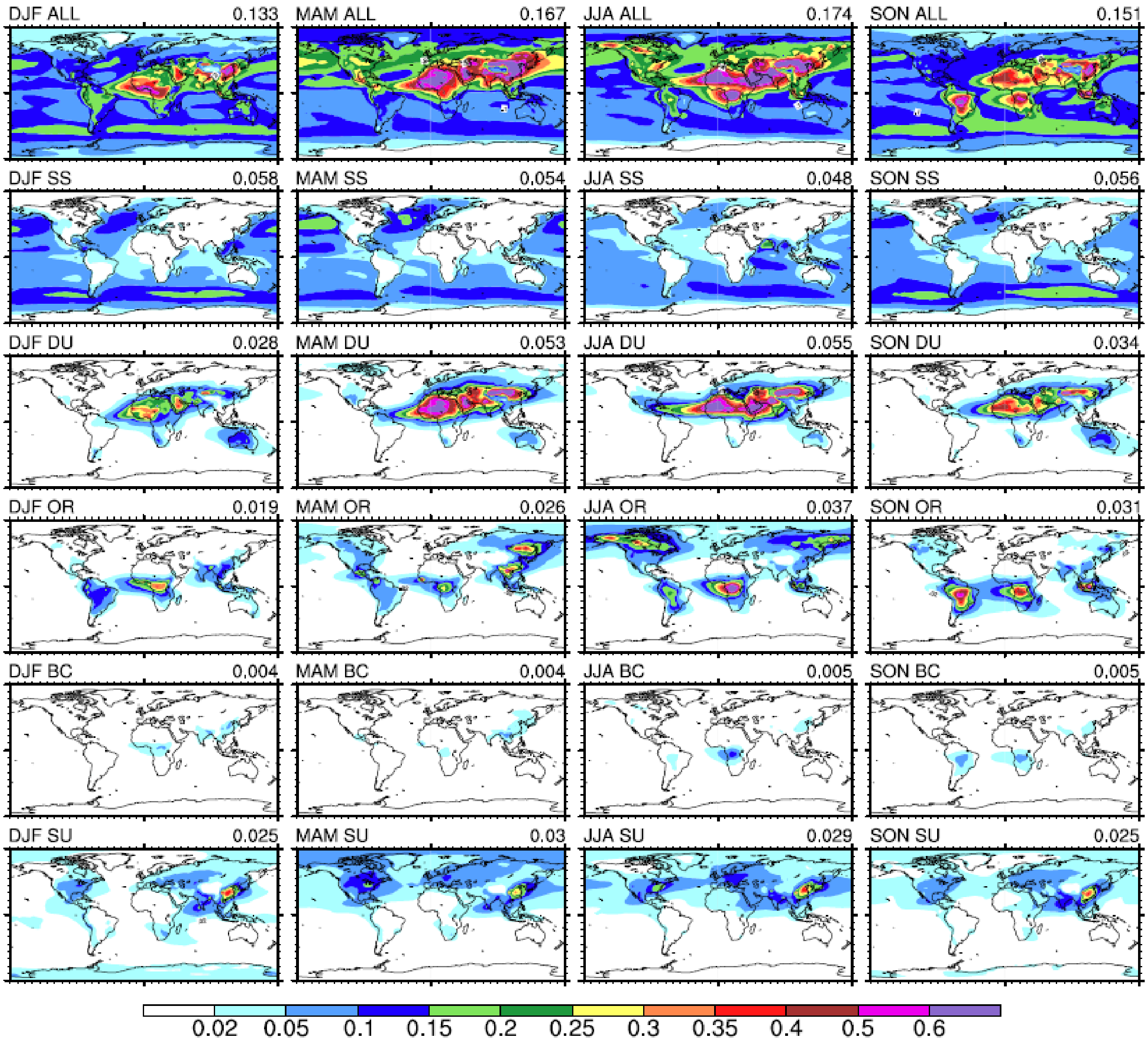


Ice nucleation scheme based on CAMS aerosols

COSMO Results for Oct-Nov 2019



Task 5: CAMS climatology in ICON-ecRAD (RHM)



Task 5: CAMS climatology in ICON-ecRad (RHM)

CAMS climatology in EXTPAR (iaot_type = 5)

11+(1) aerosol species, 4D arrays

- ✓ Compiled
- ✓ Tested
- ✓ Added in development version of EXTPAR - Waiting official version

CAMS climatology in ICON

Problems:

- ➢ No interface to read 4D or 5D variables
- ➢ A huge memory footprint for all variables

Solution:

An internal buffer to store two time slices (in the CAMS climatology case: months) of data – 3D fields

- ➢ Linear vertical interpolation

- ✓ Compiled
- ✓ Not tested

Task 6: 2D Aerosol optical depth (D. Rieger)

Prognostic equation for 2D AOD $\psi_j(x,y)$, using vertically averaged horizontal wind $\overline{\boldsymbol{v}_{H,j}}$:

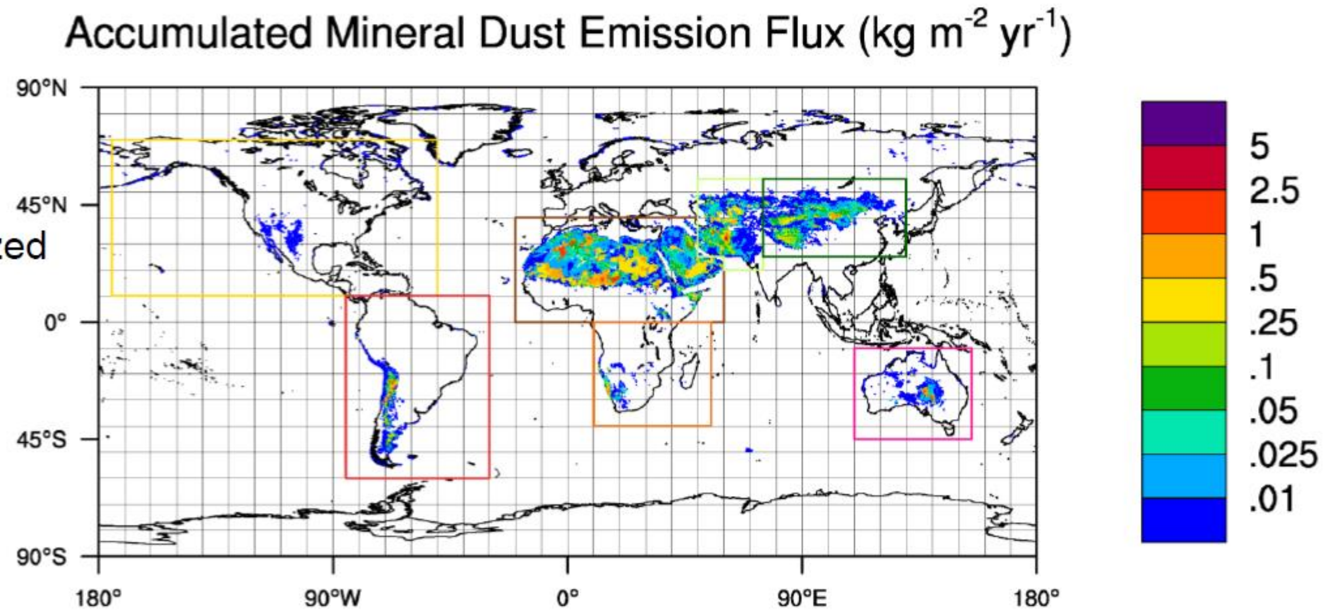
$$\frac{\partial \psi_j(x,y)}{\partial t} = \underbrace{\overline{\boldsymbol{v}_{H,j}} \nabla \psi_j(x,y)}_{\text{advection}} + \underbrace{S_{e,j} + S_{w,j}}_{\substack{\text{sources \& sinks}\\ \text{(emission, washout)}}} + \underbrace{f_{diff} \cdot \Delta \psi_j(x,y)}_{\text{artificial diffusion}} + \underbrace{\frac{[f_{clim,j} \cdot \psi_{clim,j}(x,y) - \psi_j(x,y)]}{\tau_{clim,j}}}_{\text{relaxation to climatology}}$$

Simulation:

- 10-day slices
- Whole year 2019
- R2B6 (40km)
- Init: Interpolated initialized analysis data from deterministic ICON

Result:

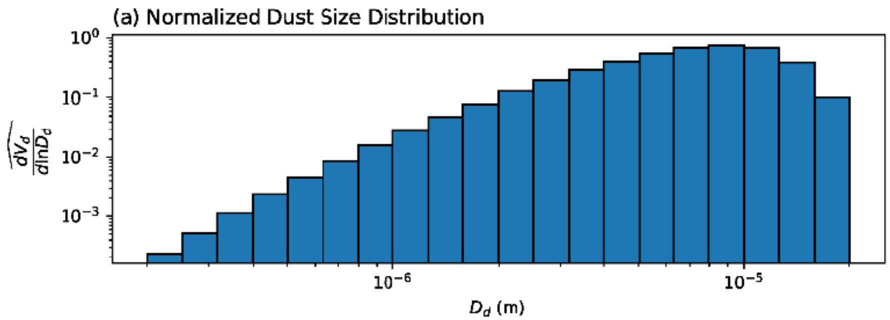
- ***3533*** $^{Tg}/_{yr}$

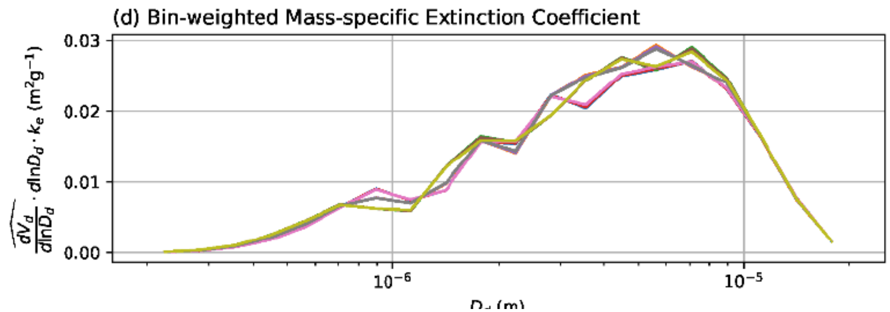


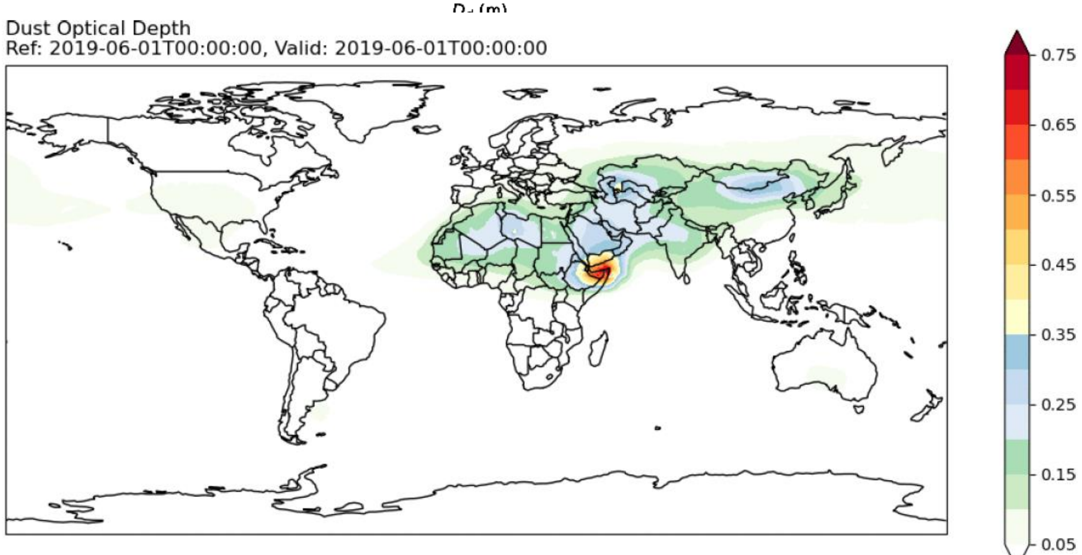
Results of the Kok et al. 2014 scheme in ICON

Task 6: 2D-Aerosol Optical Depth

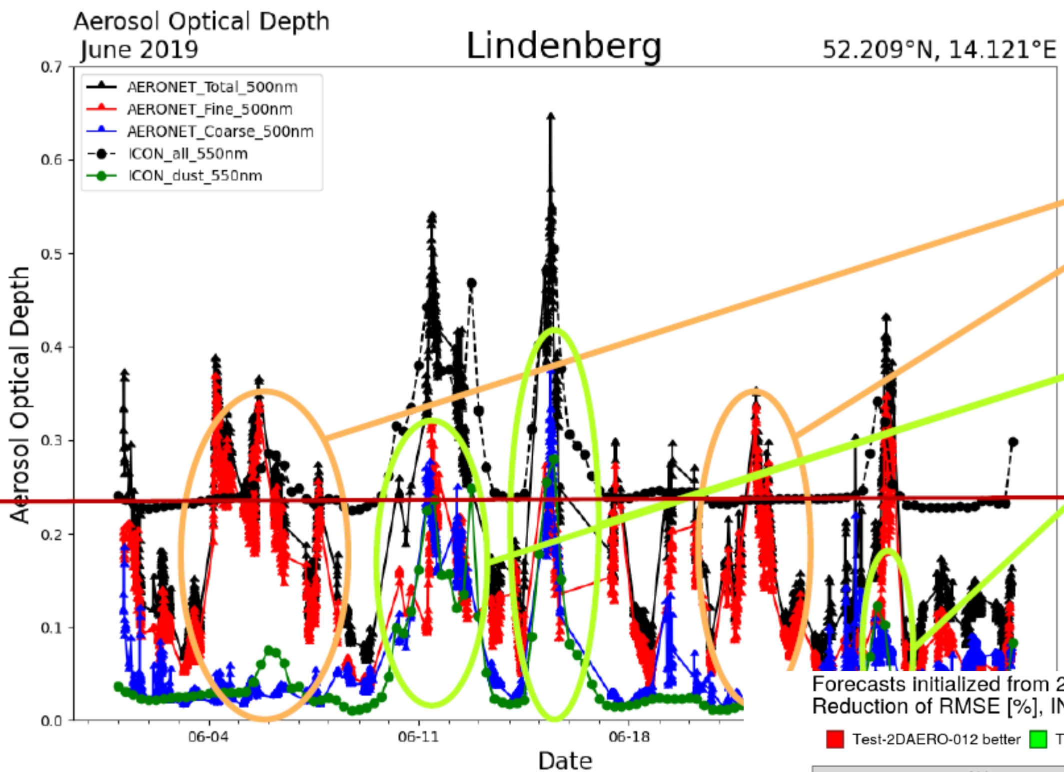
Converting Mass Flux to AOD flux







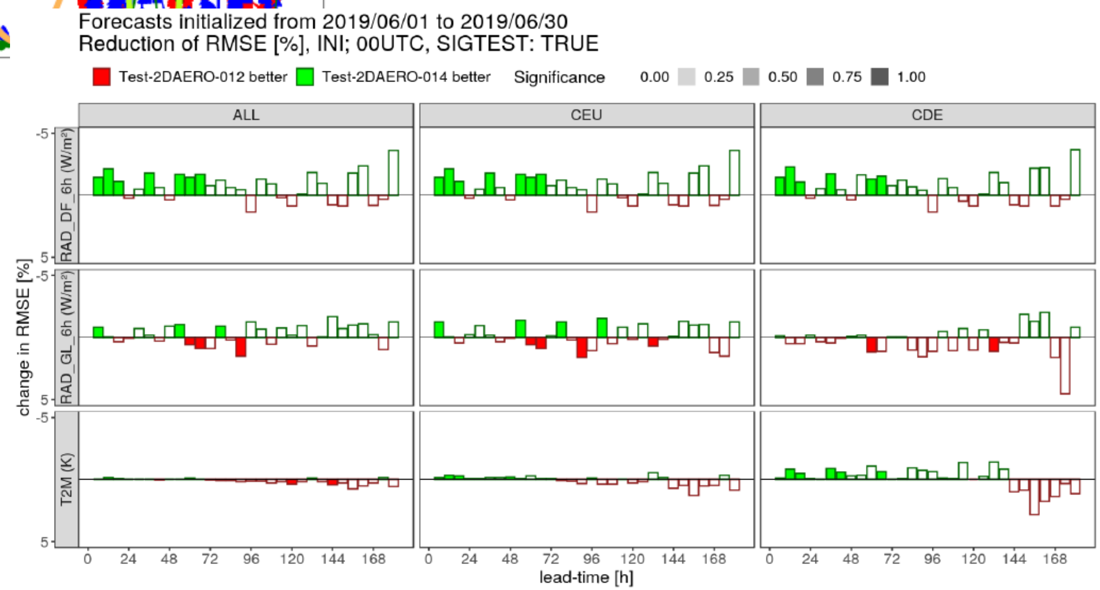
Task 6: 2D-Aerosol Optical Depth



- Fine Mode, probably anthropogenic aerosol
- WMO SDS-WAS ensemble members do not show mineral dust outbreaks as well

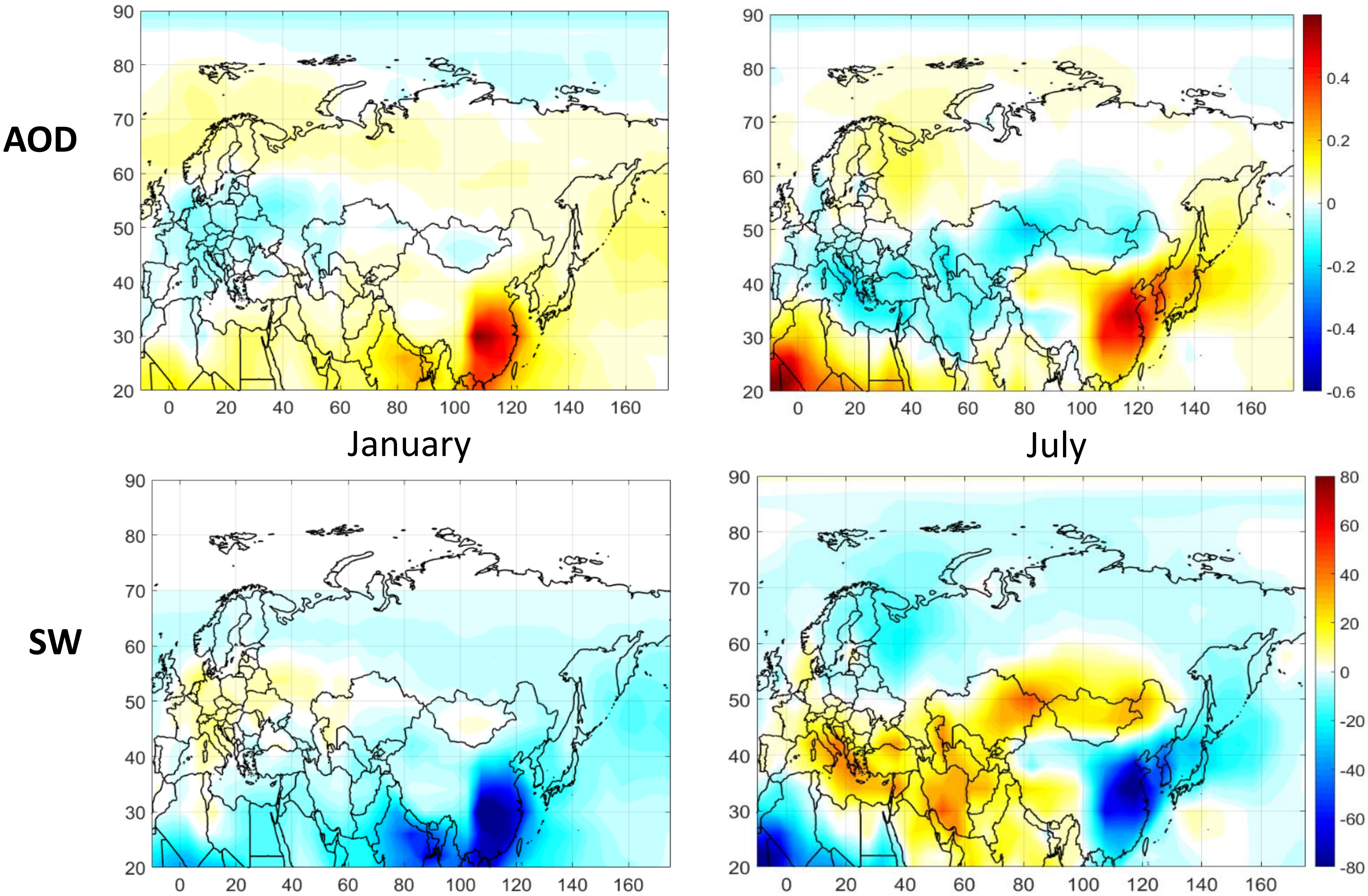
- Peaks well reproduced

- Background aerosol mostly overestimated by Tegen climatology



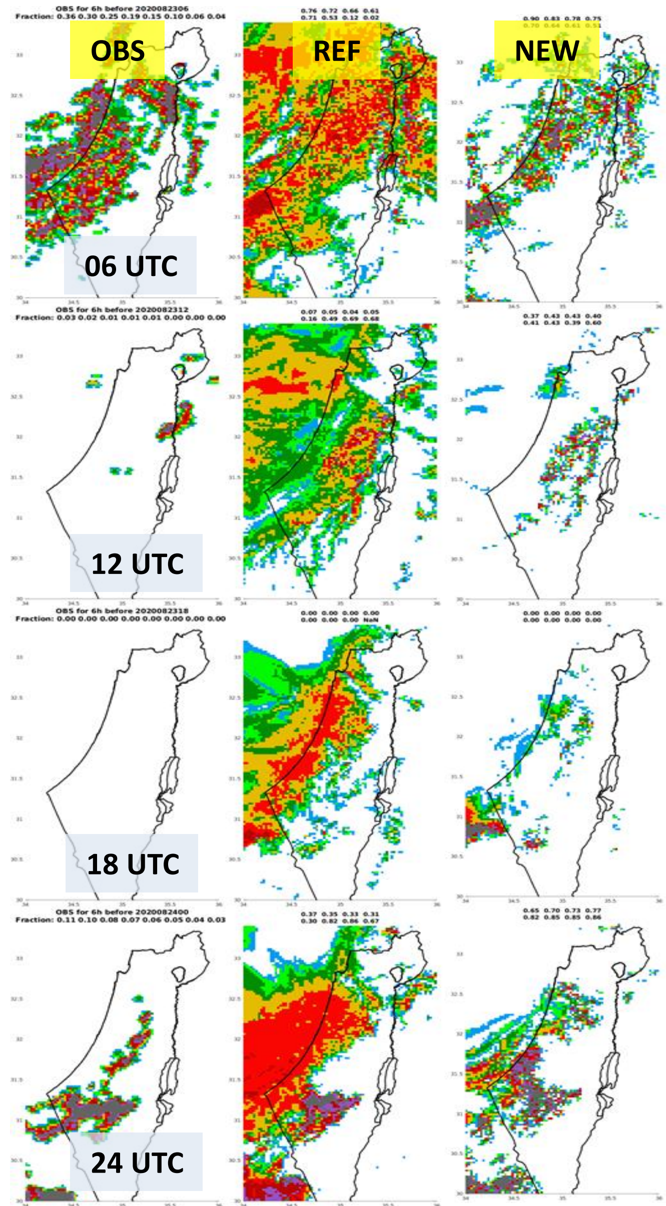
Task 7: MACv2 climatology in ICON (RHM)

Kinne-MACv2 (2013) vs. Tegen (1997)



Task 9: Correction of ICON stratiform cloud cover scheme over the Eastern Mediterranean

- Summertime: too many points with low CLC, too little points with CLC=1.
- Two main stratiform liquid cloud cover (CLC) schemes: Martin’s scheme (inwp_cldcover=1) and the ICON “COSMO” scheme (inwp_cldcover=3).
- The dependence CLC(RH) was analyzed for both schemes, using several test cases over the Eastern Mediterranean.
- A new parameter “allow_overcast” was introduced ICON scheme which allows to change the steepness of the CLC(RH) curve.
- For tune_box_liq_asy=1.7 and allow_overcast=0.63 the ICON “COSMO” CLC(RH) behavior is achieved, i.e. steep increase towards CLC=1 at RH=100%.



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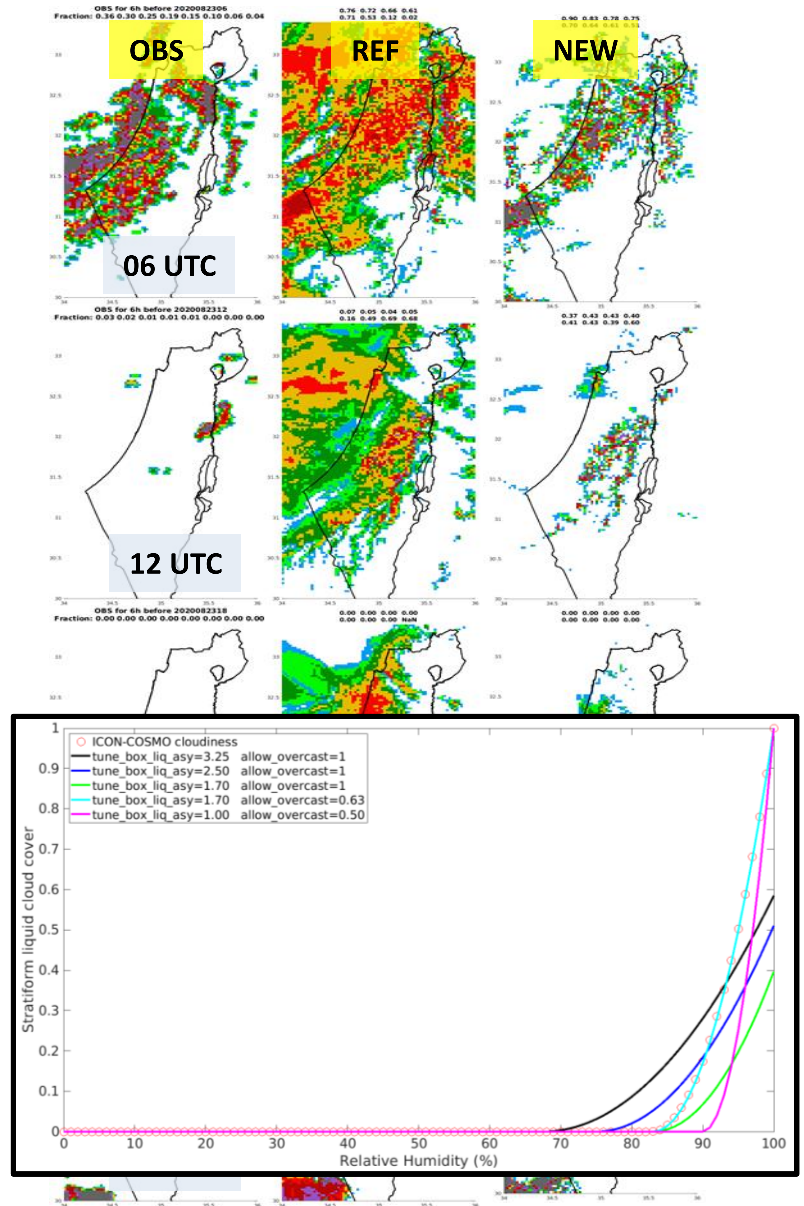
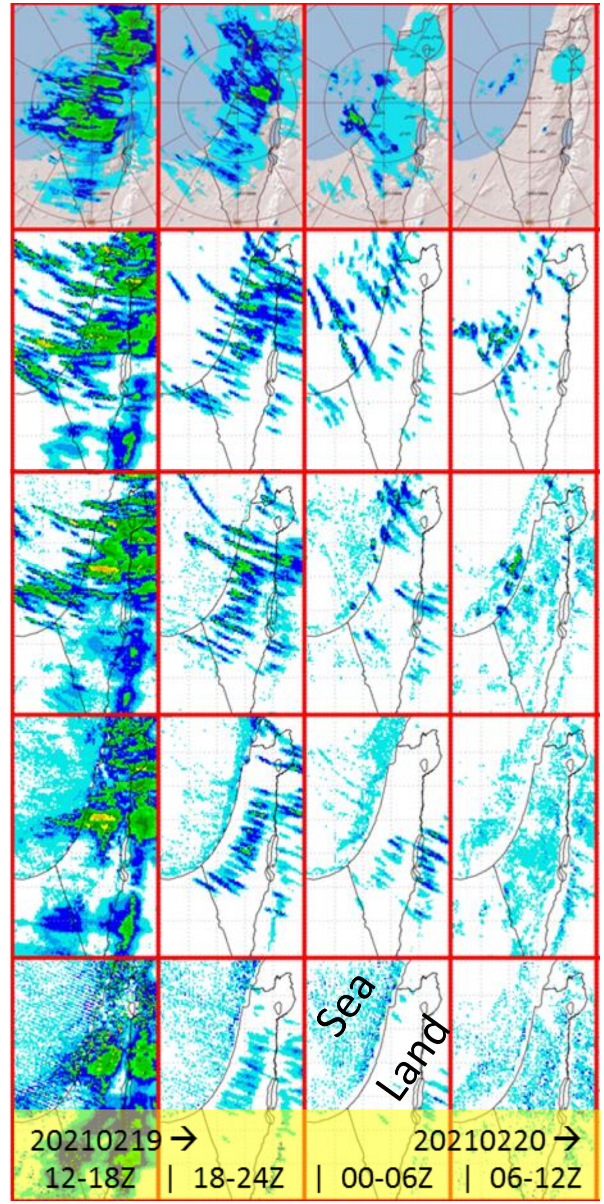


Effect of ICON shallow convection schemes on precipitation over the Eastern Mediterranean

Problem: Convection permitting models with grid spacing below ~4 km usually describe deep convection on grid scale, but still parametrize the shallow convection, being sub-grid scale process. The artificial combination of resolved and parametrized convection might deteriorate the model forecast skill, particularly precipitation



Radar

tune_rdepths

100hPa

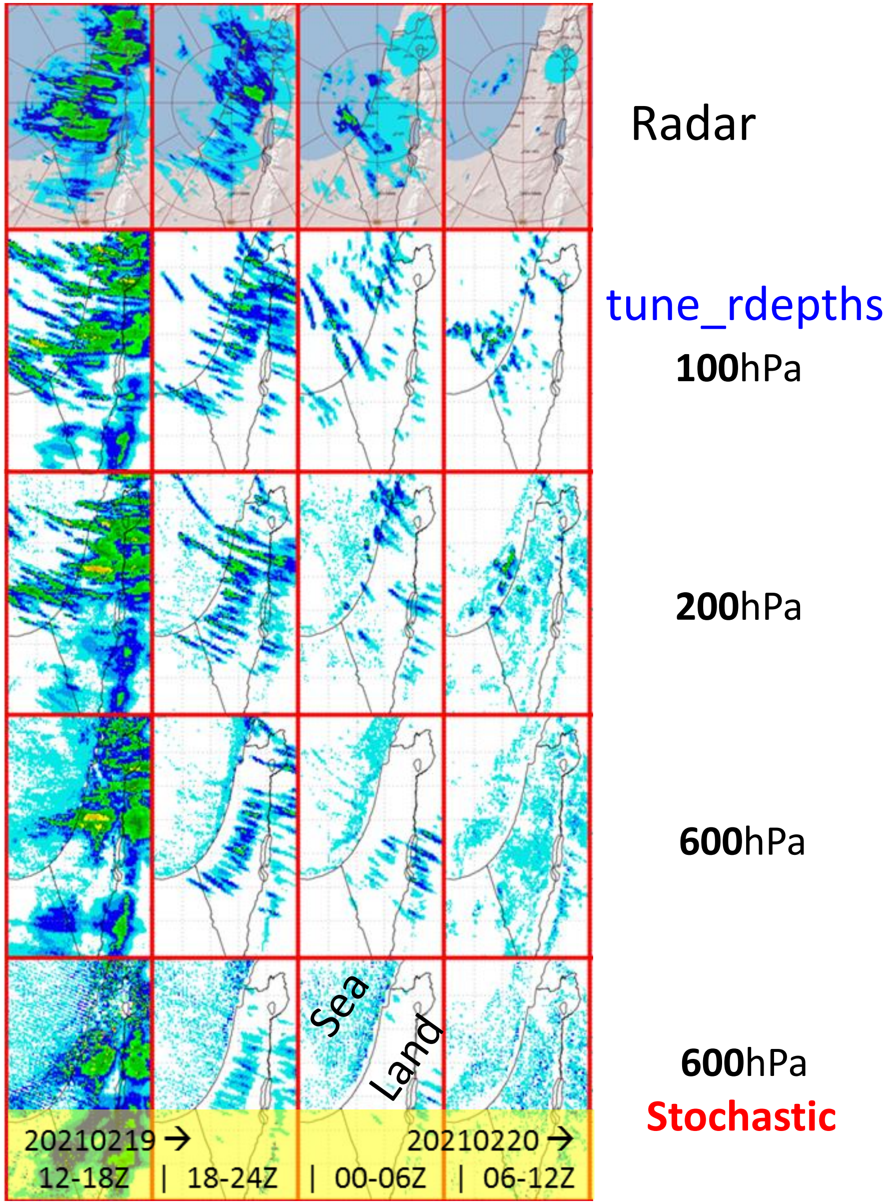
200hPa

600hPa

600hPa
Stochastic

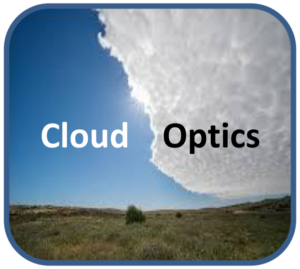
Effect of ICON shallow convection schemes on precipitation over the Eastern Mediterranean

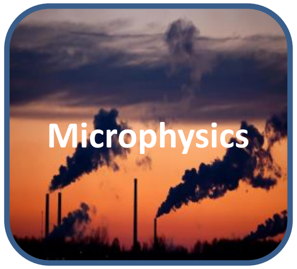
1. Optimal precipitation rates distribution is obtained when the SCP is strongly limited by limiting the development height
2. Reduction of maximum depth is a good solution for weak precipitation However, it “kills” SC which may have negative effect on other fields.
3. Increase of maximum depth increases SC precipitation but strongly decreases GS precipitation, leading to underestimation.
4. Stochastic SDE scheme improves the situation, still underestimating precipitation
5. Strange land-sea contrast in SC precipitation

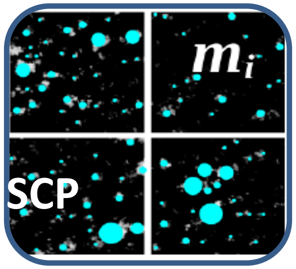


CAIIR: project overview

- Cloud optics
- Aerosols inputs: CAMS forecasted, CAMS climatology, 2D advection scheme, MACv2 climatology
- Microphysics – R_{eff} and LWC revised, Realistic cloud formation
- Clouds and precipitation improvements and the Stochastic convection scheme
- Model testing and tuning







Thank you for your attention!