Radiation Developments in HARMONIE-AROME

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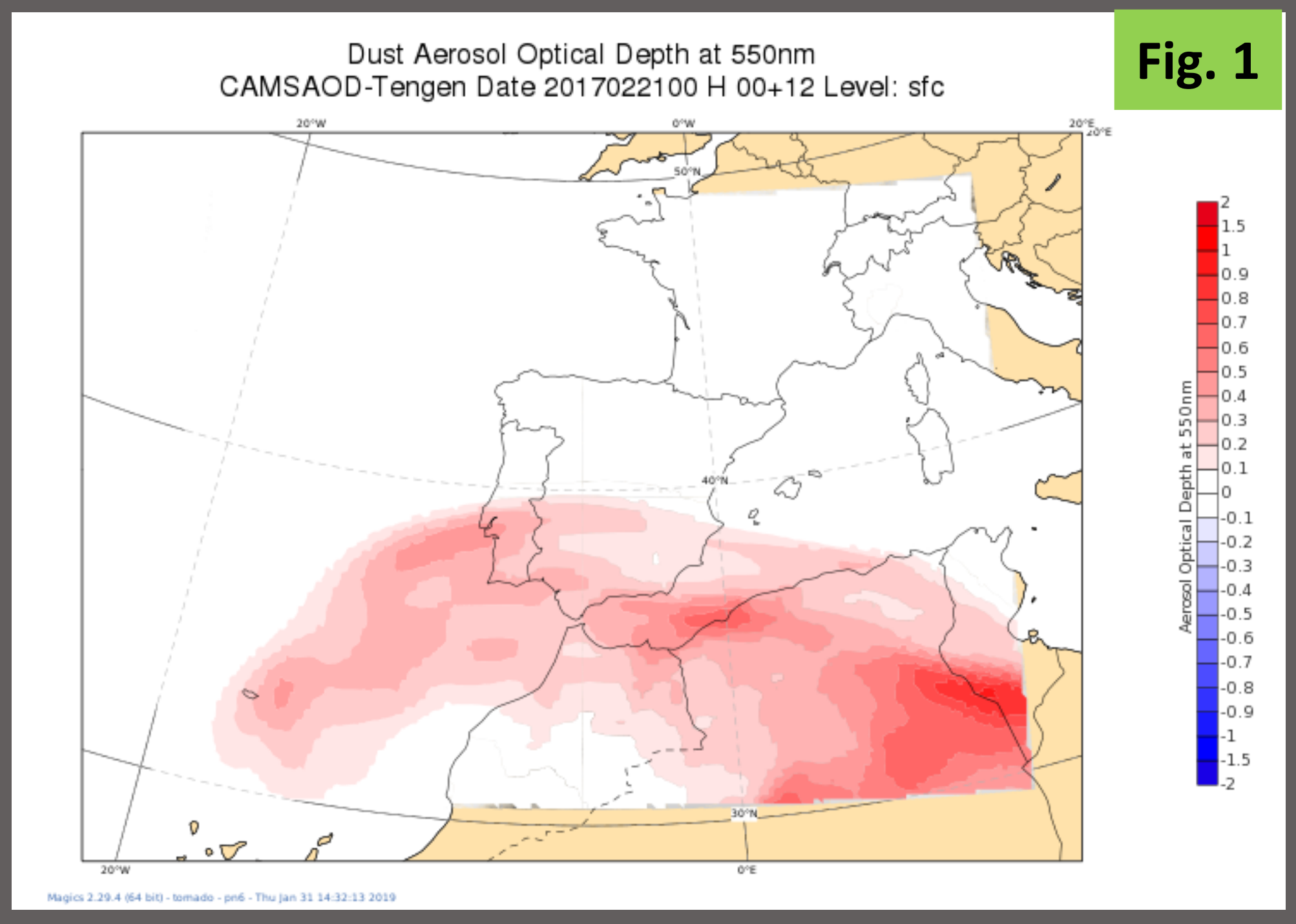
1. Summary

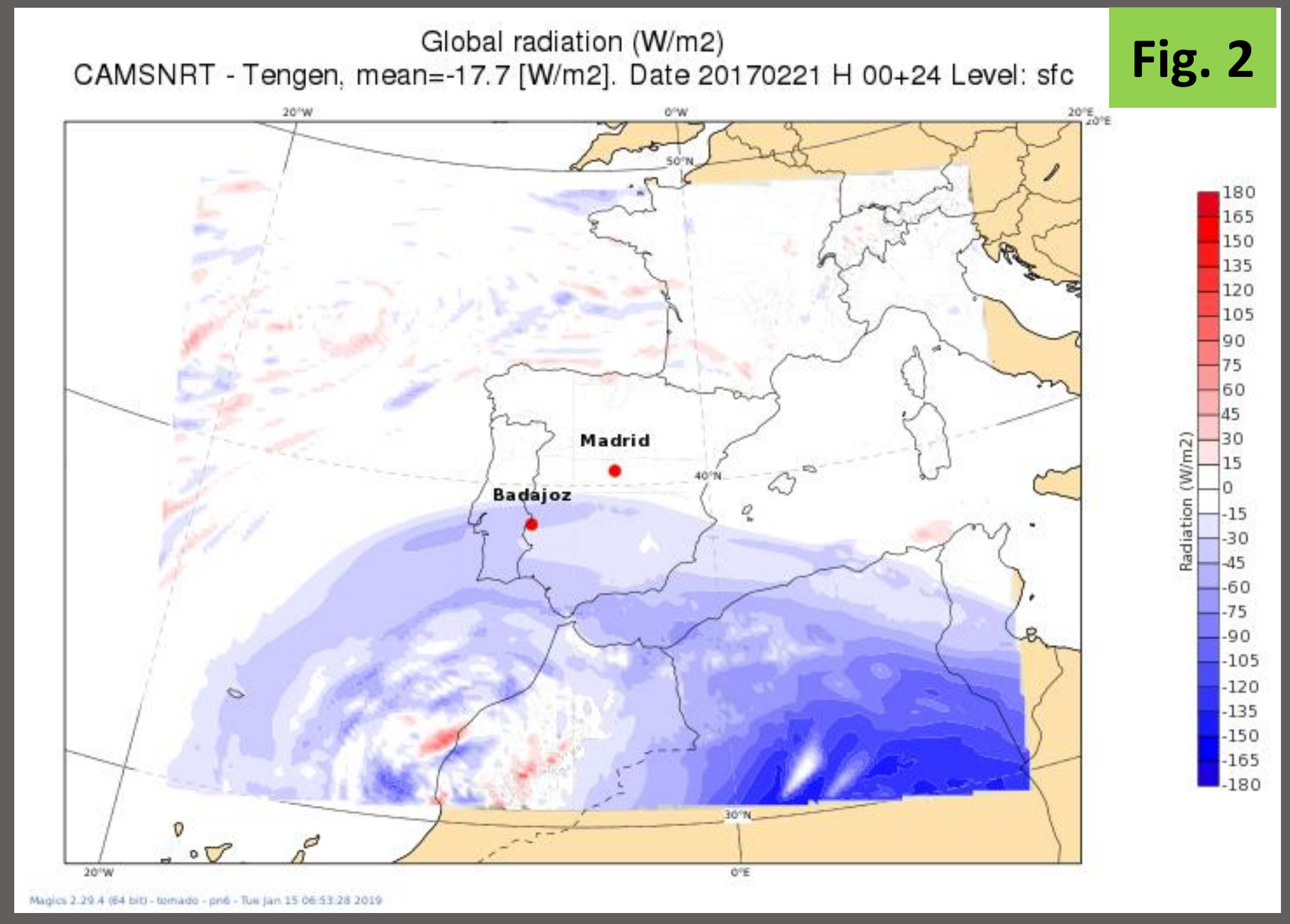
- Recent work carried out by scientists working on radiation, aerosols and microphysics using the HARMONIE-AROME configuration of the ALADIN-HIRLAM NWP system is summarised on this poster.
- In particular the following topics are covered:
    - Comparison of the Tegen [1] Aerosol Optical Depth (AOD) climatology and CAMS (Copernicus Atmospheric Monitoring Service [2]) real-time AODs for a Sahara dust case over Spain
    - First experiments on harmonising the effective radii calculations in the radiation and microphysics parametrizations
    - Uncertainties in shortwave (SW) and longwave (LW) radiation schemes

2. CAMS vs Tegen Aerosol Optical Depths (AOD)

- 3D aerosol mass mixing ratios from a CAMS forecast were introduced into HARMONIE-AROME simulations via the initial conditions and horizontal boundaries
- Default aerosol inherent optical properties (spectral dependence of AOD, single scattering albedo and asymmetry factor) available in HARMONIE-AROME were applied - constant in time and space
- Results from a case study involving an intrusion of Sahara dust over the south of the Iberian Peninsula on 19/02/2017 are shown in **Fig. 1 and 2**



- **Fig. 1** shows the difference between vertically integrated AOD for dust at 550 nm from a +12 hour CAMS forecast and the default Tegen aerosol climatology in HARMONIE-AROME
- The differences in the southeast of the domain are largest with the real-time values an order of magnitude greater than the climatology (1.0 vs 0.1)



- Corresponding impacts on daily average global shortwave radiation at the surface are shown in **Fig 2.** for a 24-h forecast starting at 00 Z on 21/02/2017
- The negative differences (in blue) over the dust covered areas are due to aerosol extinction. The maximum reduction in the average clear sky global radiation at the surface was 154 Wm^{-2} (~ 60%)
- A reduction in 2 m temperature of 1-2 degrees) around noon was confirmed by measurements at several stations over southwest Spain. Such reductions were not seen in the experiment which used the Tegen climatology

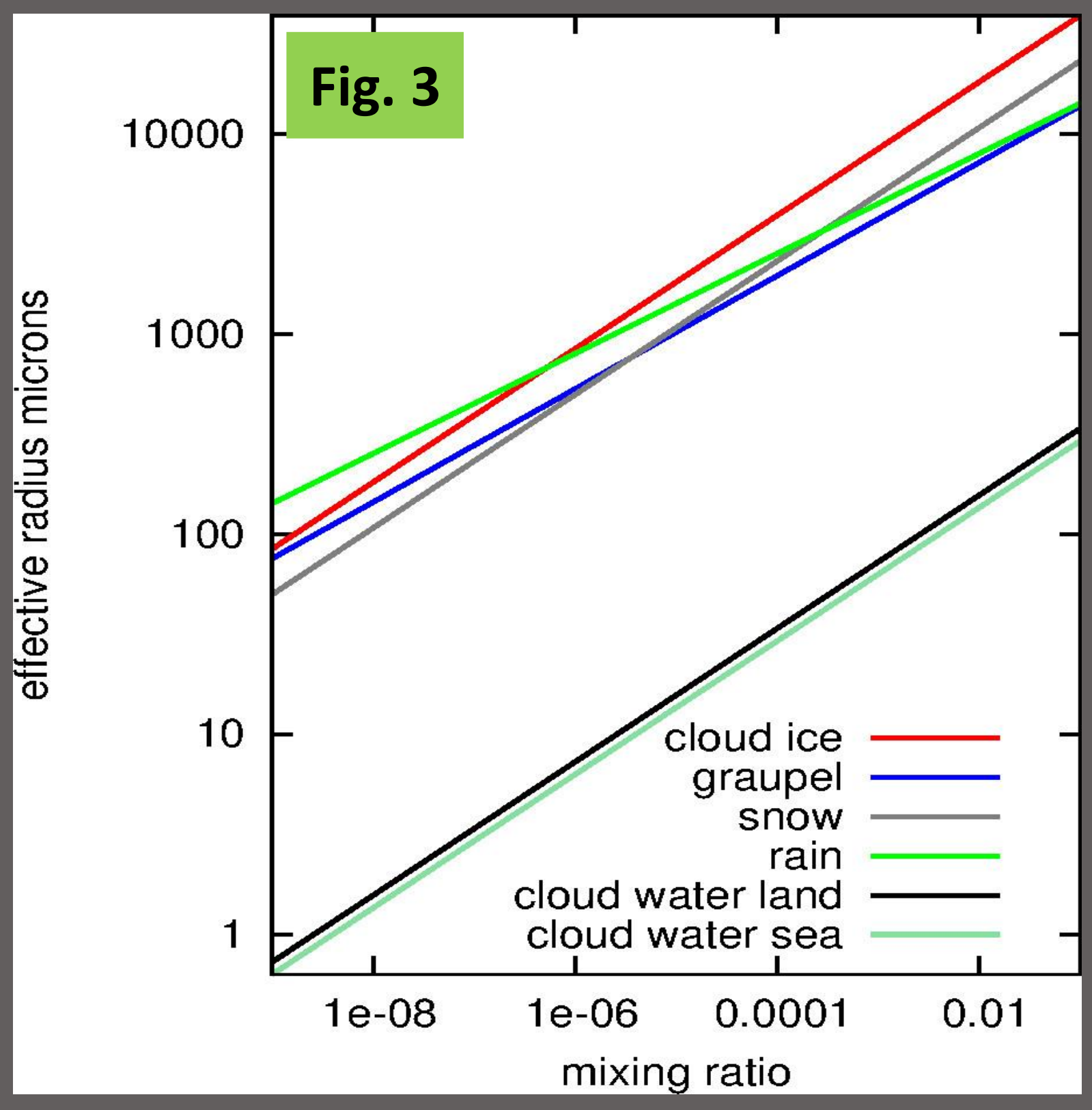
3. Effective Radii

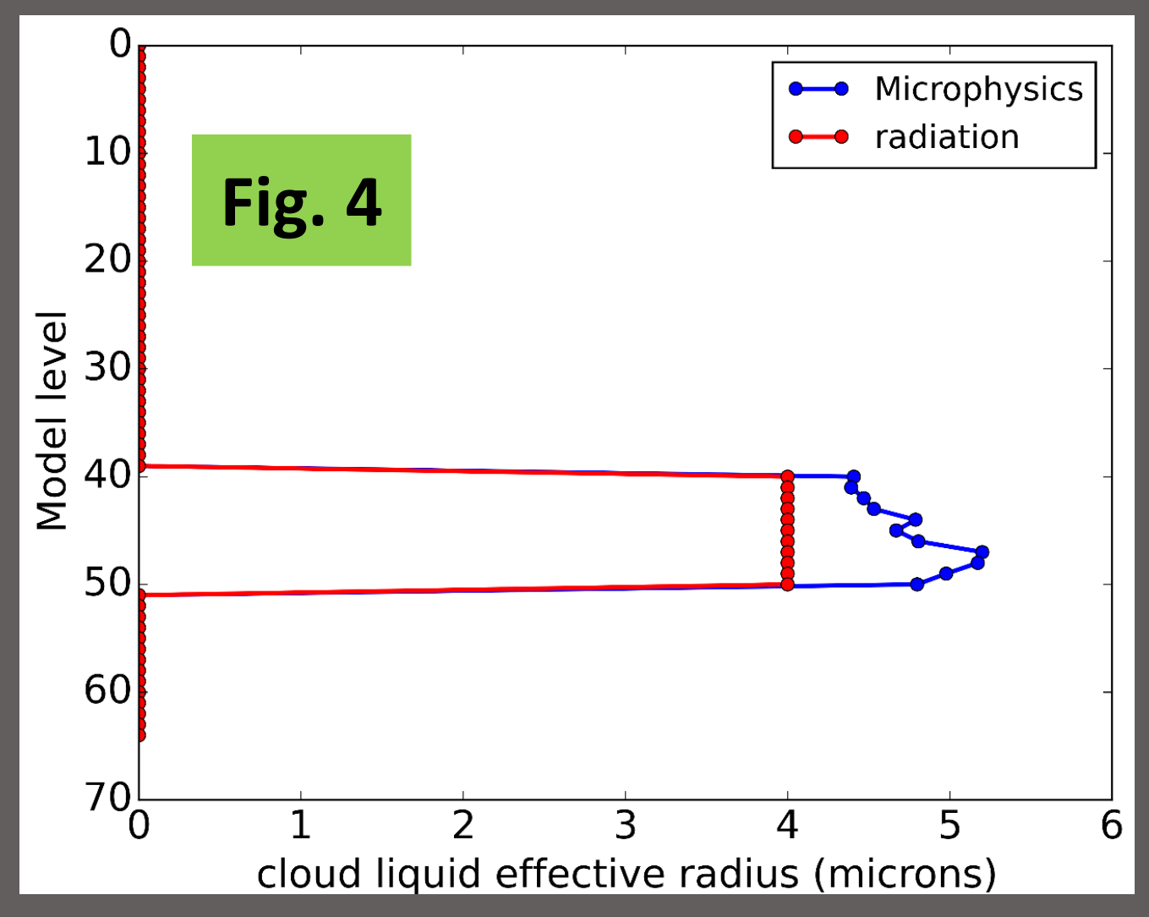
- The HLRADIA [3] broadband radiation scheme was used for the sensitivity tests shown below
- In HLRADIA the effective radius of ice particles is computed using the Sun and Rikus scheme [4], which depends on temperature and ice water concentration at each model level. The cloud liquid effective radii are calculated using the Martin et al. scheme [5] which depends on cloud water concentrations and land/sea aerosols
- By default, the ice water content used by the radiation scheme in HARMONIE-AROME includes a weighted average of the mixing rations of ice, snow and graupel (via RADSN=1/RADGR=0.5 coefficients)
- An alternative approach is to use the size distributions of microphysics species from the ICE3 scheme to derive effective radii of cloud liquid, cloud ice, snow, graupel and rain. These can then be used in the radiation scheme instead of its internal calculations
- In ICE3 the size distributions follow a general gamma function (g). Using this, the effective radius, r_e, for spherical particles is defined as

$$r_e = 0.5\frac{\int_0^\infty D_s^3 g(D_s)dD_s}{\int_0^\infty D_s^2 g(D_s)dD_s}$$

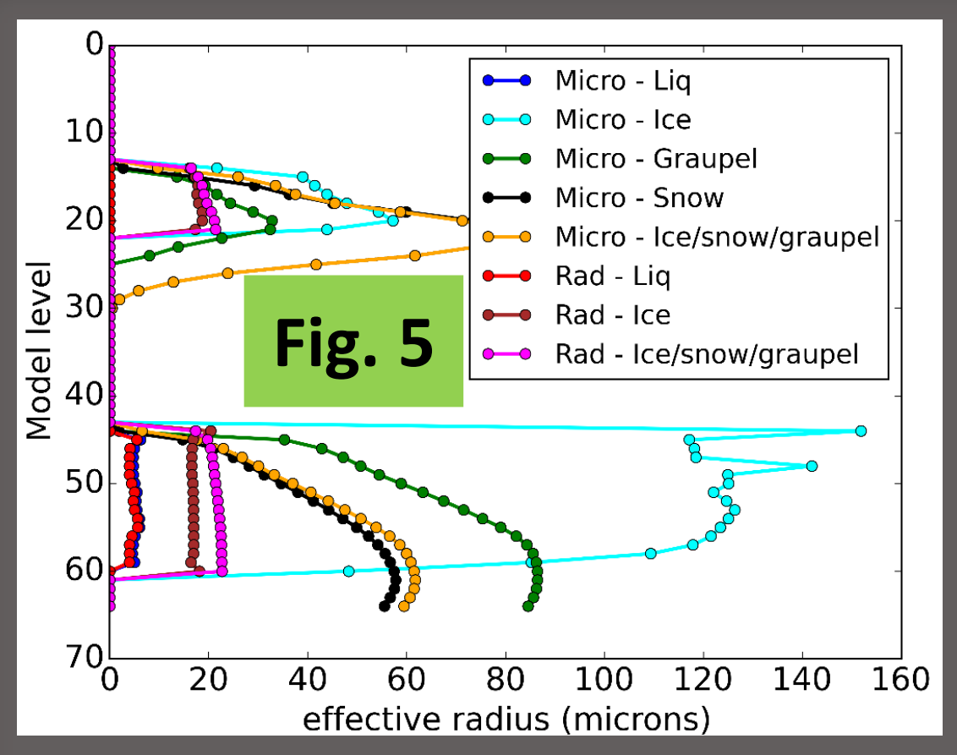
where D_s is the particle diameter and $g(D_s)$ is the size distribution function. The equation is slightly different for spherical or column-like particles

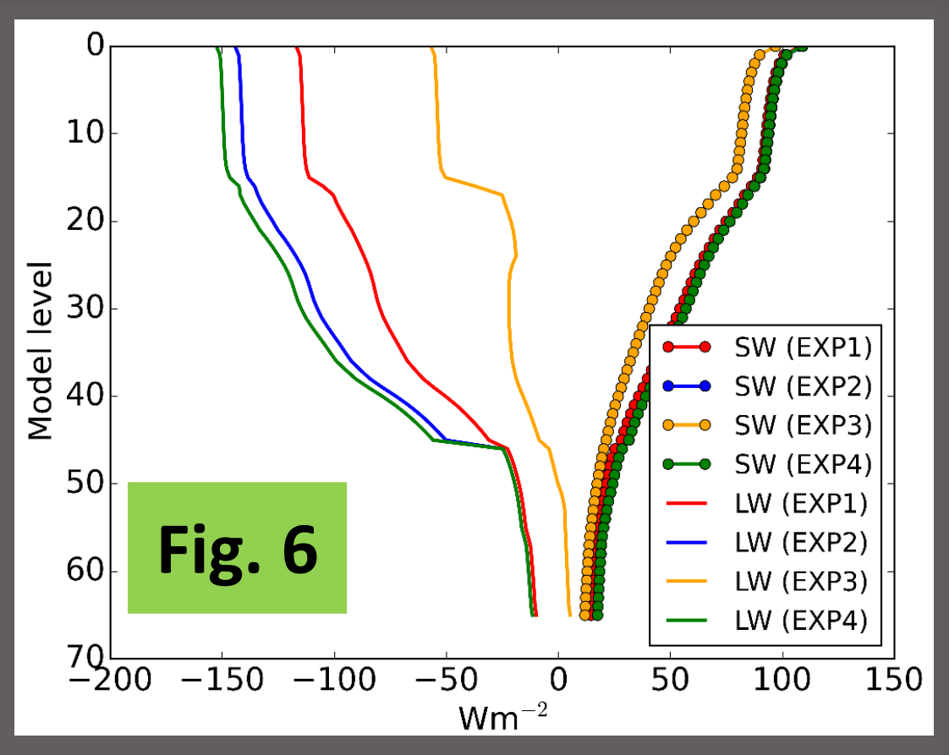
- **Fig. 3** shows the sensitivity of effective radius to mixing ratio for each particle type. Note that for cloud liquid, the size distribution depends on land/sea aerosols similar to the Martin et al. scheme





- **Fig. 4** shows an example for a point over Ireland during summer where only cloud liquid is non-zero. It shows the cloud liquid effective radius as calculated by the radiation and microphysics schemes. The differences (of the order of a micron) have a small effect on SW/LW radiation in this case (~ 1Wm^{-2} at the surface)
- A case involving cloud water and ice (location in Finland in February) is shown in **Fig. 6 and 7**. The experiment names are defined as follows:
    - **EXP1:** eff. Radius (Re) by HLRADIA with RADSN and RADGR =0 (i.e. pure cloud ice crystals without precipitating solid particles)
    - **EXP2:** Re by ICE3 used in the radiation calculations with RADSN/RADGR =0
    - **EXP3**: Re by HLRADIA with RADSN/GR=1.0/0.5. This also results in a higher ice water content (IWC) mixing ratio being fed to HLRADIA (IWC = mixture of ice, snow and graupel in this case)
    - **EXP4:** Re by ICE3 used in radiation calculations; RADSN/RADGR=0 but with snow and graupel accounted for in the ice effective radius by using a an average of the Re for ice, snow and graupel, weighted by their mixing ratios

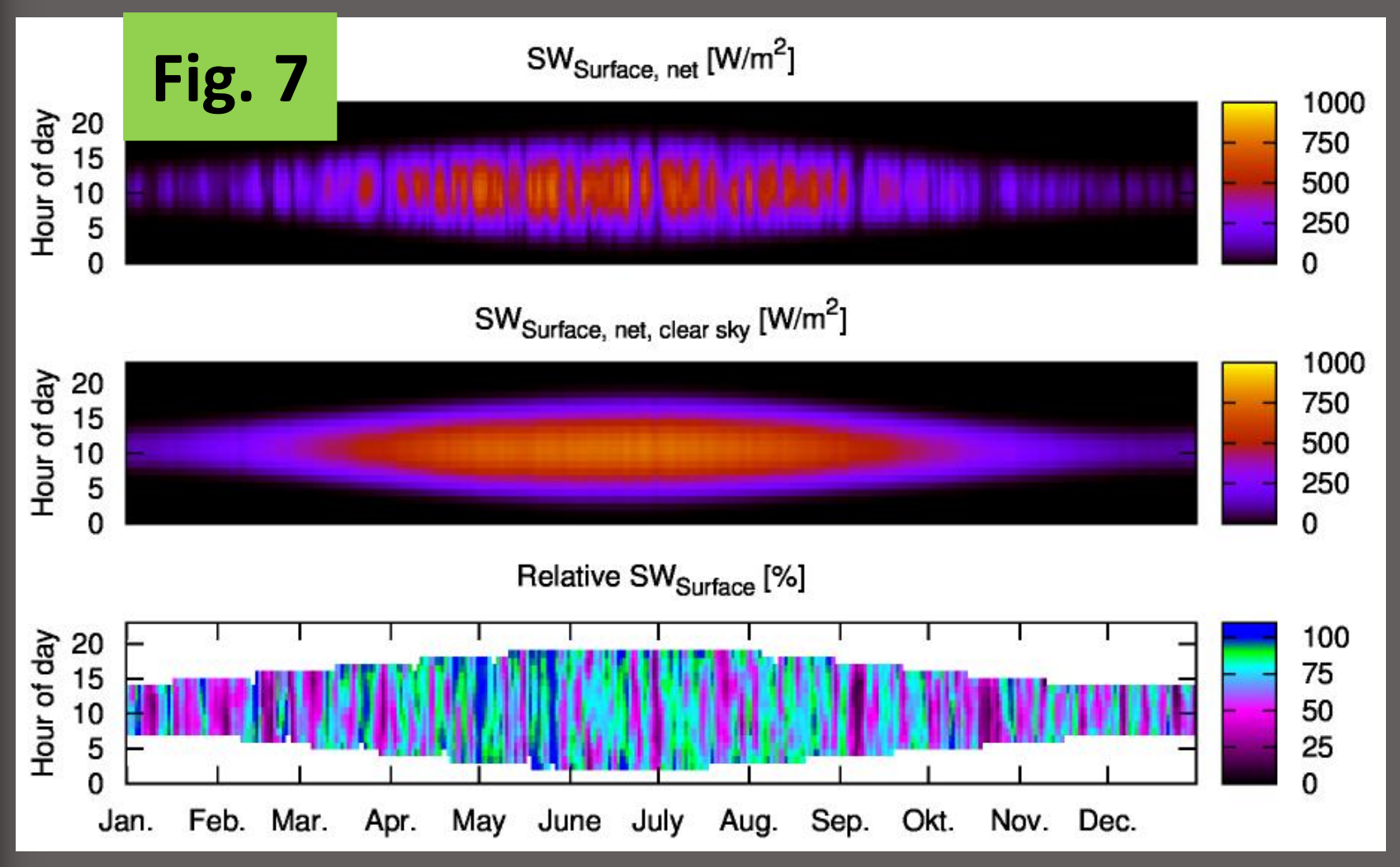




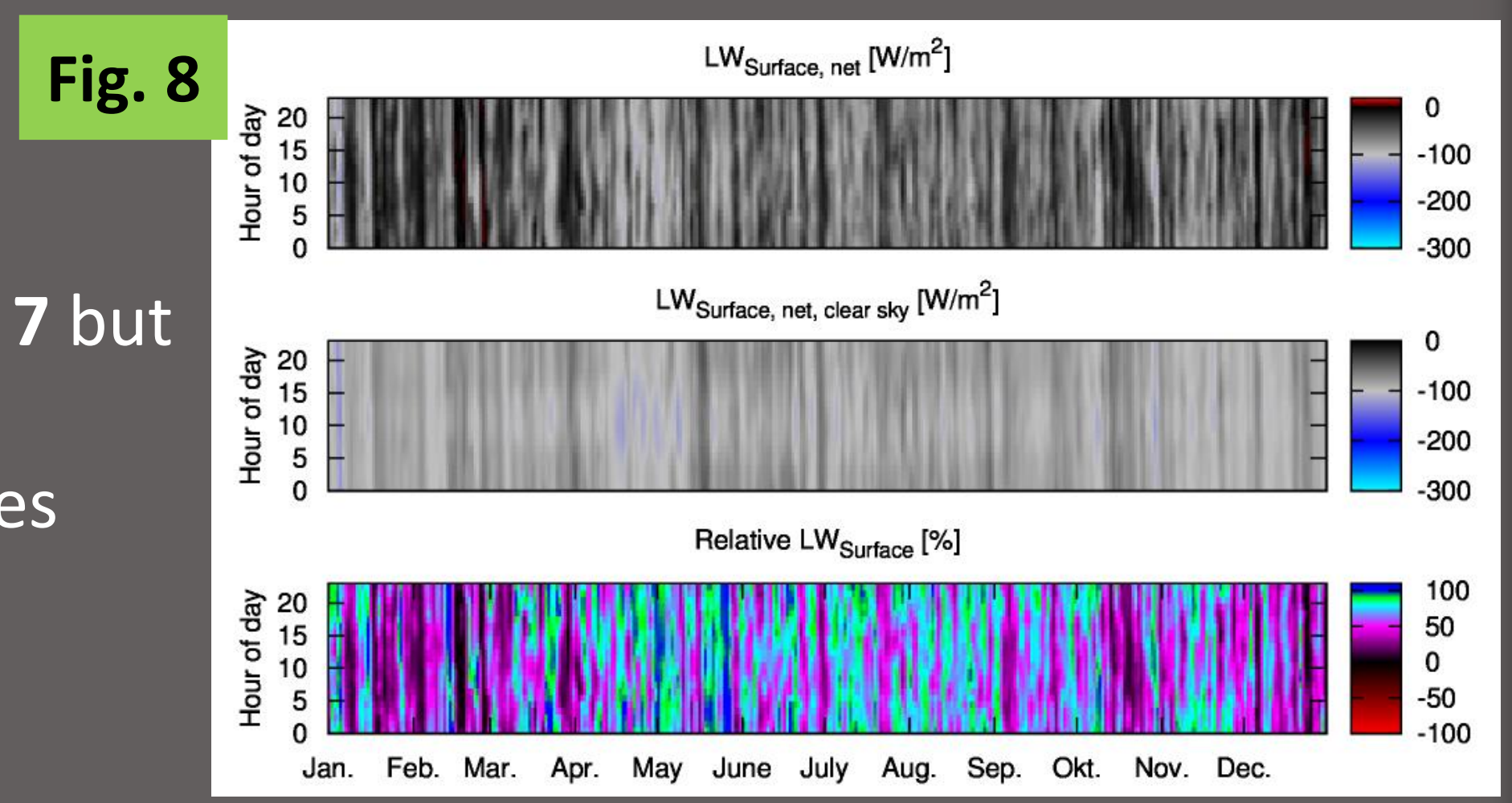
- **Fig. 5:** Comparison of the Re profiles shows that Re for cloud ice crystals, precipitating graupel and snow as well as their combination as suggested by ICE3 are larger than those by HLRADIA
- Combining ice, snow and graupel using RADSN/GR gives a much smaller Re (magenta) than combining them using the ICE3 Re and mixing ratios (orange)
- **Fig. 6**: Comparison of the net SW and net LW radiation profiles
- For SW using Re from ICE3 (EXP 2 & 4) gives similar results to when Re from HLRADIA are used (EXP1). The largest difference is seen when RADSN/GR are non-zero (EXP 3). Larger differences are seen for LW in EXP3 which needs further investigation. The differences between EXP3 and the other experiments is mainly due to the ice mixing ratio.

4. Uncertainties in Radiation Schemes

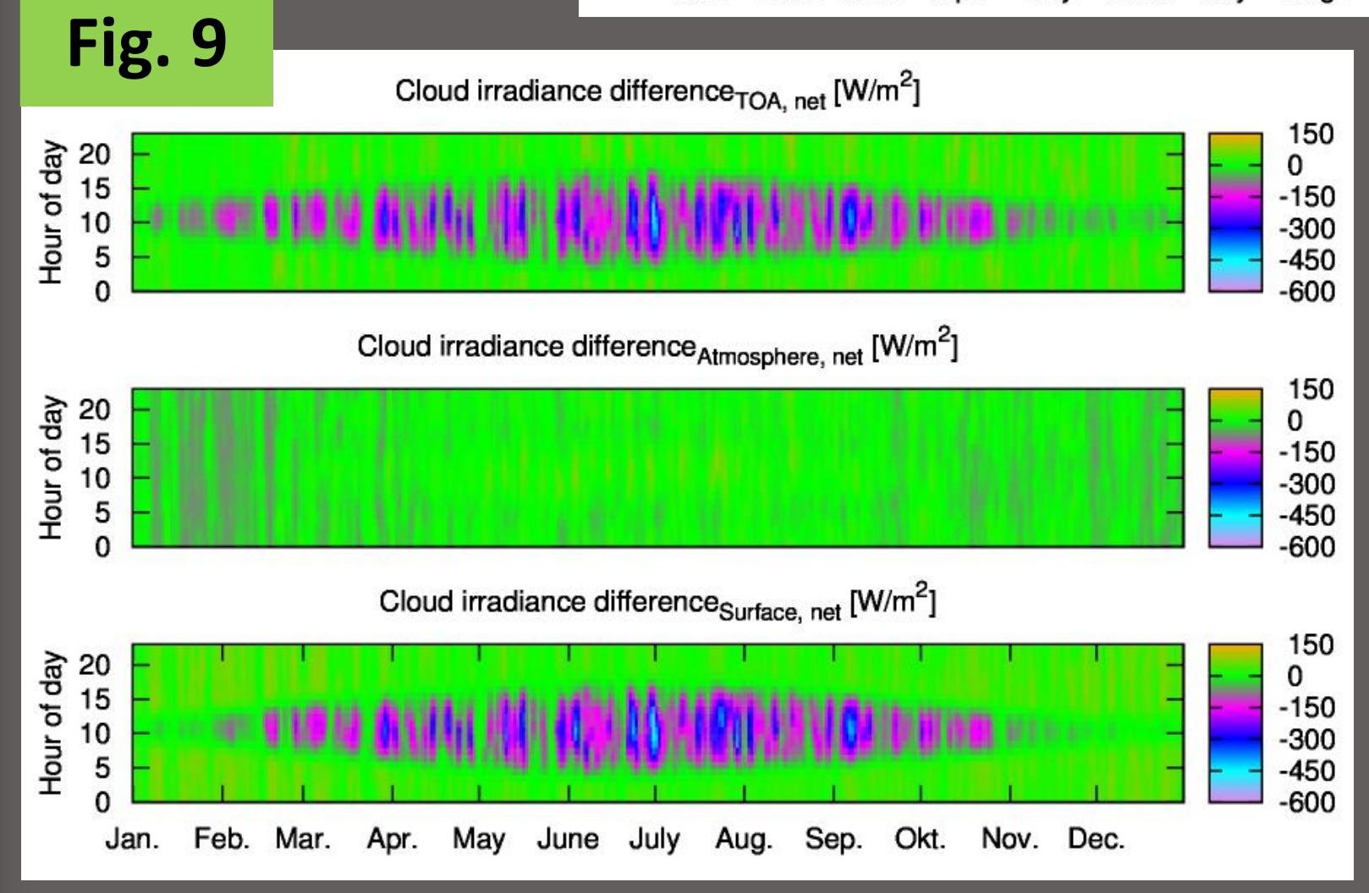
- Uncertainties in SW and LW local radiative heating rates primarily arise from the external cloud input
- Local radiative heating rates are proportional to the net irradiance, which is the difference between downward and upward irradiances on a horizontal surface
- The effect of clouds on the SW net irradiances, LW net irradiances and total net irradiances are illustrated in **Fig. 7, 8 and 9**, respectively



2017 SW net irradiances and relative cloud forcing from ERA5 for a location in Zealand, Denmark



As in **Fig. 7** but for LW irradiances



As in **Fig. 7** but the total cloud radiative forcing is shown for the TOA, atmosphere and surface

- **Fig. 7** shows that clouds can reduce the net SW surface irradiance to almost zero during daytime
- Similarly **Fig. 8** shows that clouds can increase the LW net surface irradiance to zero
- **Fig. 9** shows that the main cloud forcing is at TOA (top panel) and at the surface (bottom panel), and that these are quite similar. For all the atmospheric model levels (middle panel) the net cloud forcing only goes below - 100 W/m^2 during the coldest winter months
- Internal computations in the radiation schemes also cause uncertainties, but to a much lesser extent. These include parametrizations of optical properties, radiative transfer, 3-D effects and surface-radiation interactions

References: **[1]** Tegen et al., 1997 **[2]** https://atmosphere.copernicus.eu/ **[3]** Rontu et al., 2017 **[4]** Martin et al., 1994 **[5]** Sun and Rikus, 1999