Shortwave Radiation in HARMONIE Comparisons and Improvements

Emily Gleeson[1], Kristian Pagh Nielsen[2], Laura Rontu[3], Ján Mašek[4]

[1]Met Éireann, Dublin, Ireland. [2]DMI, Copenhagen, Denmark. [3]FMI, Helsinki, Finland. [4]CHMI, Prague, Czech Republic.

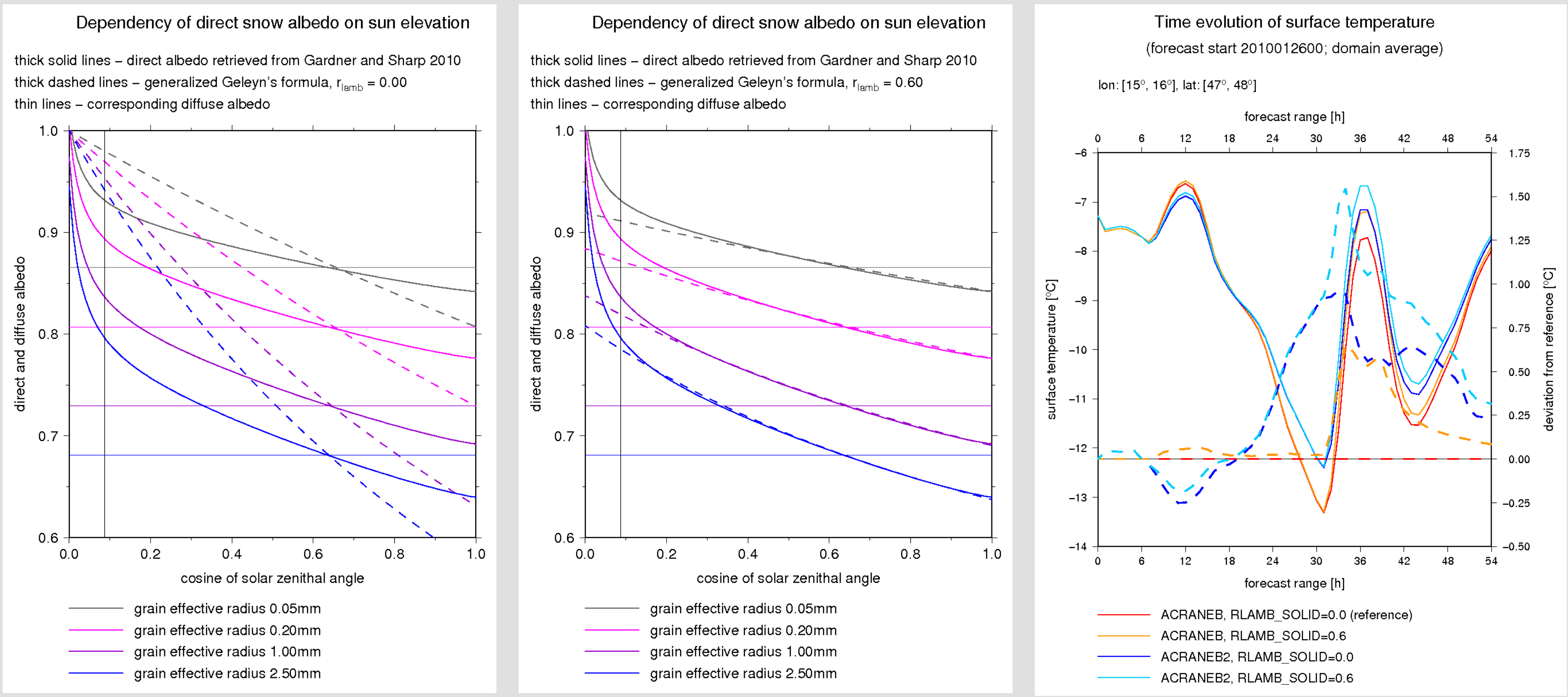
1. Introduction

- High resolution NWP models resolve more details about local weather. Accurate treatment of cloud-radiation interactions and surface-radiation interactions thus becomes increasingly important in order to produce reliable weather forecasts.
- This work involves the use of **HARMONIE-MUSC cycle 38.1** and the accurate 1D radiative transfer model **DISORT** for testing the short-wave (SW) radiation parametrizations in HARMONIE.
- The IFS cy27 SW radiation scheme is the default scheme in **HARMONIE/AROME**. We have implemented 2 additional radiation schemes: **HLRADIA** (from HiRLAM, 1 SW band) and **ACRANEB** (v.2. from ALARO, 1 SW band).
- We are working on comparing and improving all 3 of these schemes. The first comparison results are already available in the discussion paper by Nielsen et al., 2014 [1].

2. Model Set-ups

- Settings used in DISORT and MUSC unless otherwise stated: Date=March 20th (equinox), altitude=0m, solar zenith angle=56°, surface albedo=0.18, AFGL mid-latitude summer atmospheric profile, no aerosols, 41 hybrid levels.
- In MUSC only the SW fluxes for the first time-step were considered in order to exclude the interactions between radiation and the evolving atmospheric state.
- In the cloudy experiments, the cloud layer is an homogeneous layer between 1 and 2 km above the surface.
- DISORT is run in the libRadtran framework for the full SW spectrum of the Kato correlated-k algorithm with absorption coefficients from the HITRAN 2000 database and an angular discretisation of 30 streams. The Hu and Stamnes and Fu parametrizations were used for calculating the liquid cloud and ice cloud optical properties respectively.
- Within the IFS radiation scheme, Fouquart (default), Slingo and Nielsen SW liquid cloud optical property schemes are available and the Fu and Liou and the Fu cloud ice optical property schemes are present [2,3]

3. Tuning of Direct Snow Albedo in ACRANEB

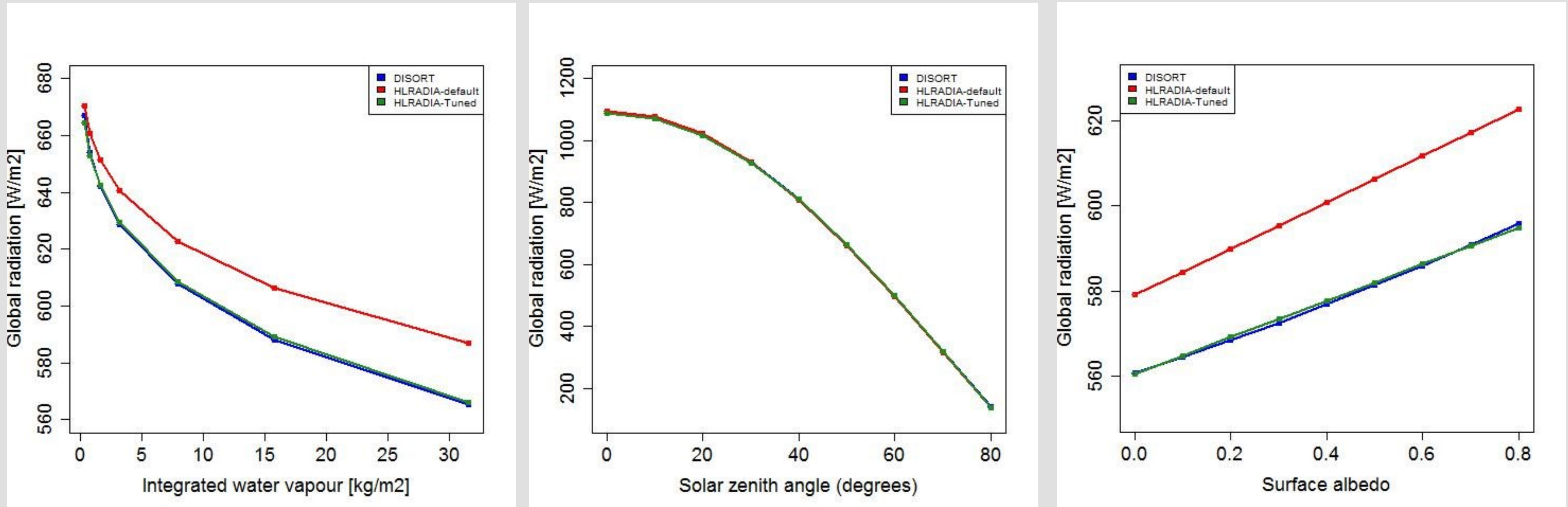


left Direct snow albedo given by Geleyn's formula (dashed) versus the Gardner and Sharp 2010 clearsky values (solid). ***centre*** Similar to the figure on the left but where the generalized Geleyn's formula with r_lamb=0.6 was used. ***right*** Time evolution of surface temperature averaged over a 1 degree by 1 degree domain, obtained from a 54 hour ALADIN/CHMI forecast (first day was overcast; second day was clear).

- In the original ACRANEB radiation scheme, the dependency of direct surface albedo on solar zenith angle (SZA) was given by the heuristic Geleyn formula.
- While this describes reflections from undisturbed water surfaces quite well, its use for other surfaces is not optimal because it exaggerates the dependency on the SZA.
- We made the equation more general by including a proportion of Lambertian reflection, r_lamb for each type of surface (land, snow, ice) which reduces the dependency on SZA.
- The left and centre figures show the snow albedo for the default Geleyn equation and where r_lamb=0.6 is introduced and Gardner and Sharp reference data are shown.
- The Geleyn's formula overestimates direct snow albedo for low sun elevations and underestimates it for the high sun elevations.
- The inclusion of the r_lamb=0.6 factor makes the match nearly perfect everywhere except for very low SZAs.
- In the January 26th test run (right most figure), a difference of ~0.6C is seen at noon, when the new albedo scheme is applied.

4. Clear Sky Tuning in HLRADIA

- Our initial clear sky HARMONIE-MUSC experiments (integrated water vapour, solar zenith angle and albedo) using the HLRADIA radiation scheme showed that HLRADIA was ~4% biased compared to DISORT.
- We varied 3 of the coefficients in the below clear sky global downward surface short wave radiation equation [4]: zabswv (C1) = 0.11, mucoeff (C2)=0.25 and bluesky (C3) =0.07 where zabswv and mucoff are associated with the integrated water vapour and bluesky is associated with backscattering from reflected beams.
- A range of values of these coefficients was tested for clear sky experiments with no aerosols under varying integrated water vapour, SZA and surface albedo.
- Approximately 100,000 runs with varying coefficients yielded the following optimum values for zabswv, mucoff and bluesky respectively: 0.125, 0.26, 0.055.

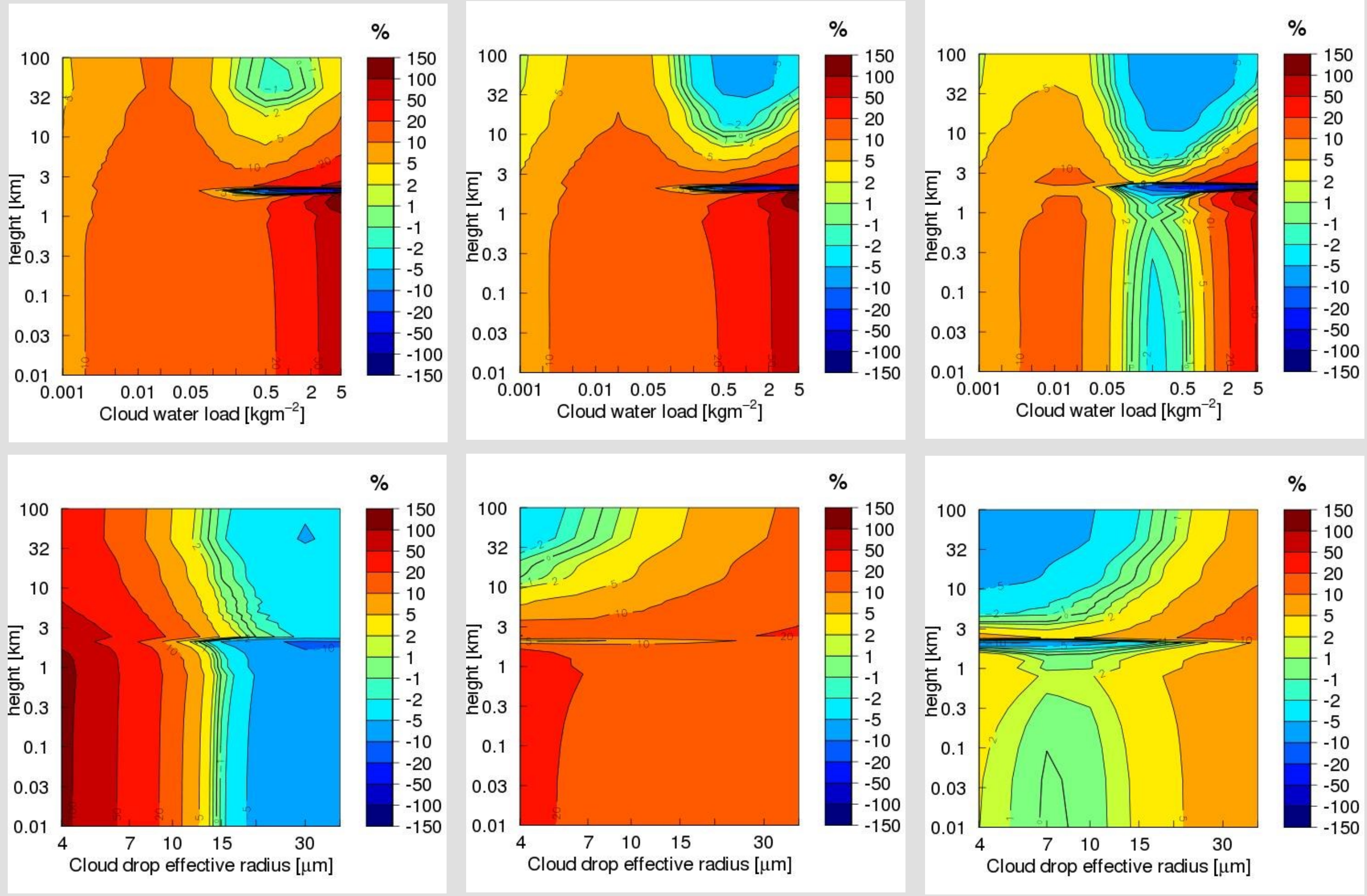


Comparison of DISORT, default HLRADIA and newly tuned HLRADIA for the following cases: ***left*** Integrated vapour experiment ***centre*** solar zenith angle experiment and ***right*** surface albedo experiment.

Note that the tuning reduces the HLRADIA clear sky bias to mostly <0.2%.

$$S\downarrow(sfc) = S_0 sinh\{1 - 0.024(\sin h)^{-0.5} - C1\left(\frac{u}{sinh}\right)^{C2} - \left(\frac{0.28}{1+6.43.Sinh} - C3\alpha\right)\}$$

5. Other HLRADIA developments in the HARMONIE radiation branch

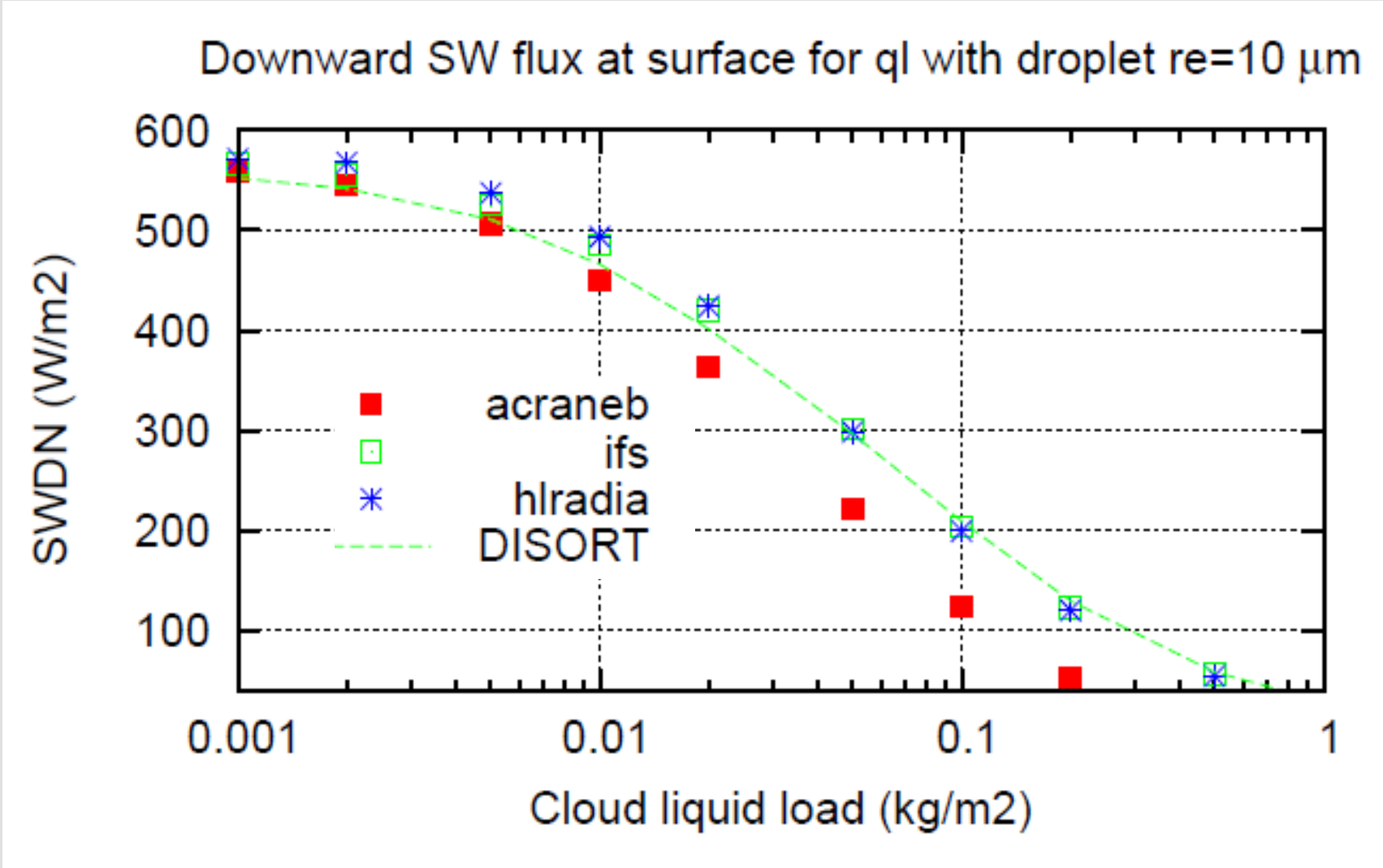


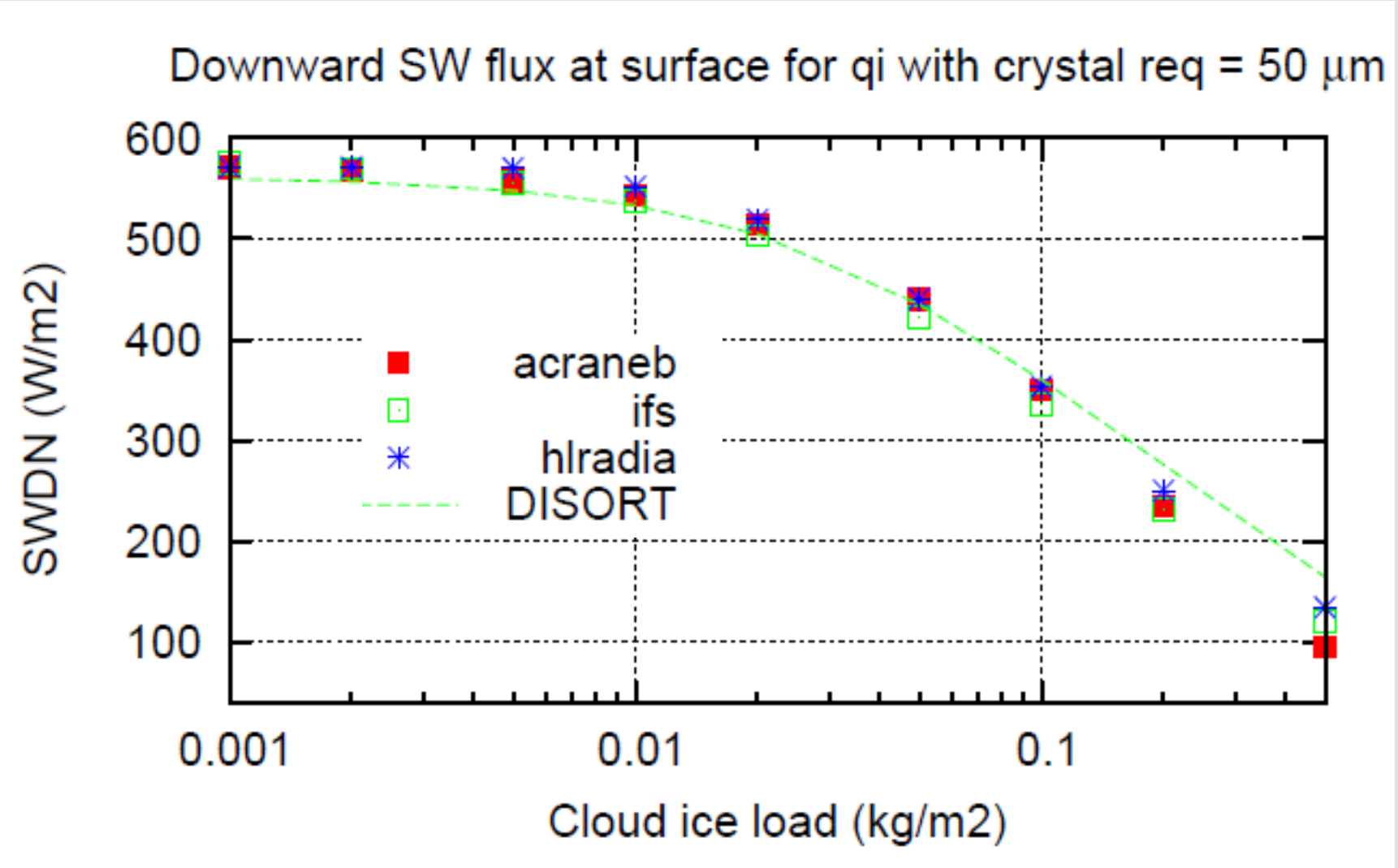
Top figures: Net flux differences for varying cloud water loads (cloud drop effective radius = 10 µm). ***Left*** Old result, ***centre and right*** new results with the SW inhomogeneity factor set to 0.8 (default) and 1.0 respectively. **Bottom figures:** Similar to top figures except that the cloud water load was set to 0.1 kg/m2 while the effective radius was varied.

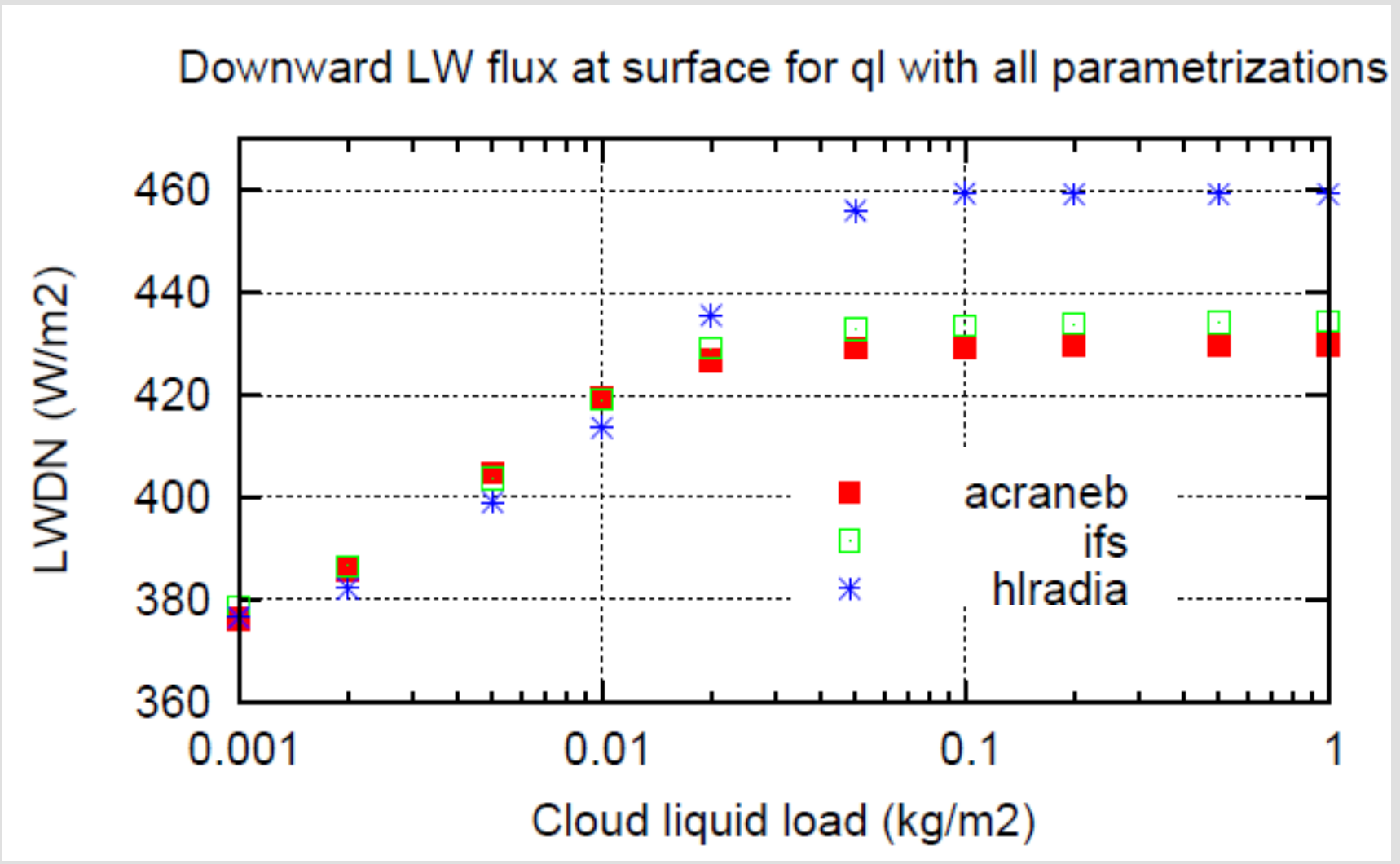
- Aerosols were included in the simulations presented in this section and DISORT was run using the SBDART pseudo-spectral calculations that are based on the LOWTRAN 7 atmospheric transmission code of Pierluissi and Peng. This is in contrast to the Kato/HITRAN parametrization shown in all of the other sections of this poster.
- At last year's ASM, our results (due to a hard-coding bug) gave the impression that the HLRADIA scheme performed badly for liquid clouds.
- Here we present sample HLRADIA results for liquid clouds again, showing tests where the cloud load was varied for a fixed cloud drop effective radius and where the effective radius was varied for a fixed cloud water load.
- In addition we also tested the affect of the SW inhomogeneity factor. This is an empirical coefficient multiplied by the cloud water or ice load in order to account for the fact that many clouds cannot be considered homogeneous layers in a coarse resolution model. Here we show that in high resolution HARMONIE a value of 1.0 instead of the default value of 0.8 gives better results compared to DISORT.
- The performance of using HLRADIA for liquid cloud shortwave calculations is found to be of similar quality to using the IFS radiation scheme.

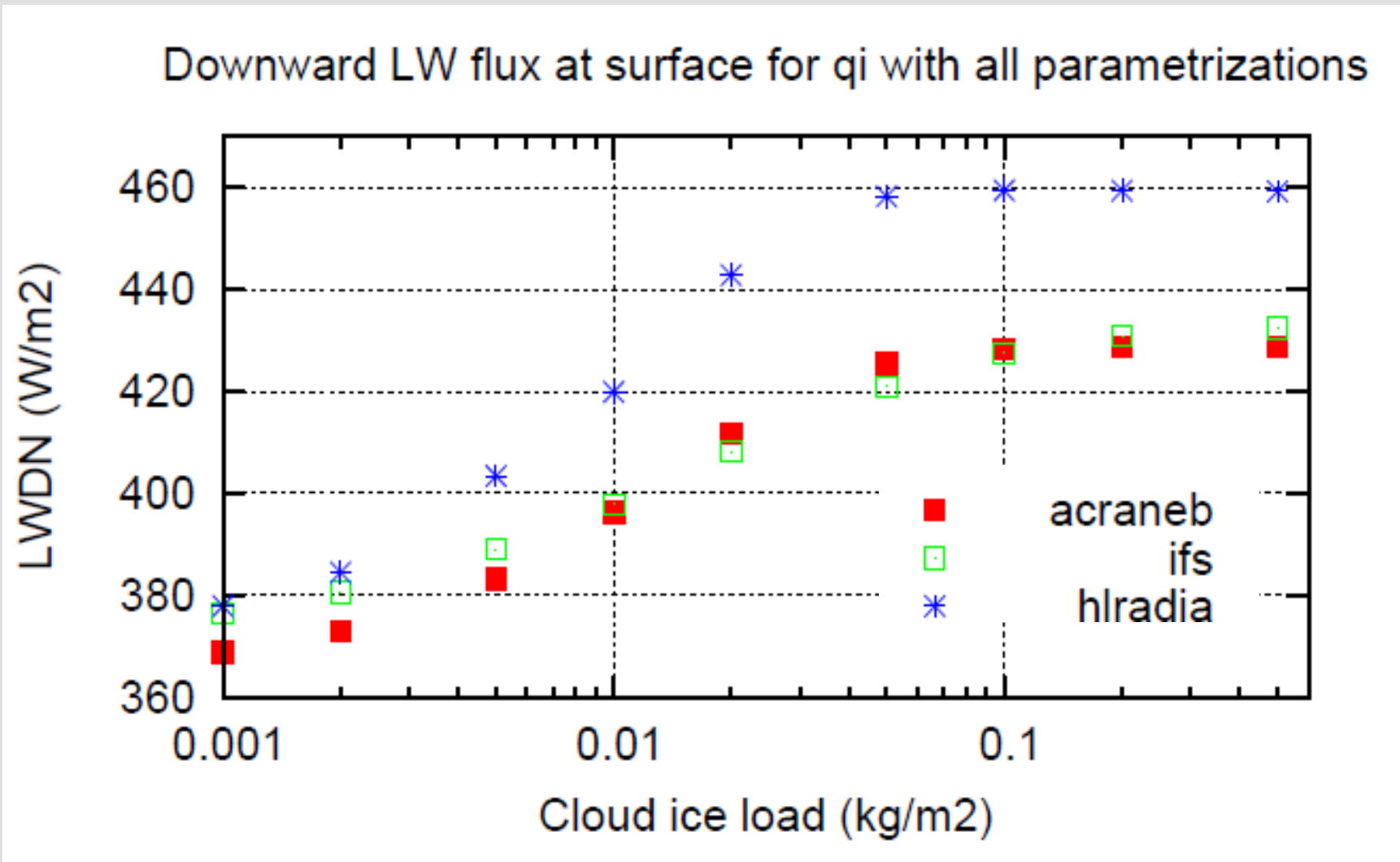
6. Comparison of cloud water/ice SW and LW fluxes in HARMONIE

- Here we compare the global SW surface radiation fluxes in HARMONIE-MUSC as a function of cloud liquid and ice loads using the IFS, HLRADIA and ACRANEB SW radiation schemes.
- The IFS scheme used incorporated the new Nielsen cloud liquid optical property scheme while for the cloud ice optical properties the Fu parametrizations were applied. HLRADIA contained the new clear sky tuned coefficients.
- All three schemes slightly overestimated SW transmission through the least dense clouds and underestimated the flux when the cloud ice load increased. Compared to DISORT and the other schemes, ACRANEB also underestimates the transmission for dense water clouds.
- We also compare the surface downwelling LW radiation for the IFS default RRTM scheme with cloud optical parametrizations by Fu and Smith-Sh and the default LW parametrizations in HLRADIA and ACRANEB.
- The ACRANEB and IFS results are similar while HLRADIA seems to overestimate the LW flux for dense liquid clouds and all ice clouds.









7. System aspects

- Currently our radiation development work is being done in the framework of the HARMONIE-38h1.radiation branch. The radiation code in this branch has been imported to HARMONIE-MUSC cycle38 experiments for testing in the single-column environment.
- We aim to set up the HARMONIE-40h1.radiation branch as soon as cycle 40 is available in the HARMONIE framework. Cycle 40 will include a flexible physics-dynamics interface to AROME and ARPEGE-ALARO physics. Radiation code has been chosen as a test bench for development of this new interfaces.
- Our goal is to implement the 3 radiation schemes (IFS (default), HLRDIA and ACRANEB) in both apl_arome and apl_par in the new physics-dynamics interface.
- We also aim to have all of our radiation updates included in regular cycle 41t (and 41h)

8. Planned work

Shortwave Radiation:

- 3D testing of setting the SW and LW inhomogeneity factors to 1.0.
- 3D testing of the new Nielsen SW liquid cloud optical property parameterisation.
- Carry out the suite of SW tests using ACRANEB to compare to DISORT, IFS and HLRADIA.
- Remove the first of the 6 SW bands in the IFS scheme.
- Include a variable cosine angle of diffuse irradiances.
- Test the Lambertian correction of albedo
- Test using the IFS SW McICA parametrization (from cy32 onwards).

Longwave Radiation:

- Do a thorough study of the LW radiation schemes in HARMONIE in a similar manner to the one we have done on the SW schemes.

Aerosol effects

- Test and develop aerosol-HLRADIA in HARMONIE, compared to IFS and ACRANEB for both SW and LW radiation.

References:

[1] K. P. Nielsen, E. Gleeson and L. Rontu, Radiation sensitivity tests of the HARMONIE 37h1 NWP model, submitted to Geoscientific Model Development, 2013.
[2] Fu, Q. (1996). An Accurate Parameterization of the Solar Radiative Properties of Cirrus Clouds for Climate Models, J. Climate, 9: 2058-2082.
[3] Fu, Q., P. Yang & W. B. Sun (1998). An Accurate Parameterization of the Infrared Radiative Properties of Cirrus Clouds for Climate Models, J. Climate, 11: 2223-2237.
[4] Savijärvi, H. (1990). Fast radiation parameterization schemes for mesoscale and short-range forecast models. Journal of Applied Meteorology, 29(6), 437-447.

FINNISH METEOROLOGICAL INSTITUTE