Shortwave Radiation Parameterisations in HARMONIE

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

[1] Met Éireann, Dublin, Ireland
[2] DMI, Copenhagen, Denmark
[3] FMI, Helsinki, Finland

1. Introduction

- Here we show results from 6 shortwave radiation sensitivity experiments using the DISORT accurate 1D radiative transfer model ([1]-[7]) and the HARMONIE-MUSC 37h1 1D model with AROME physics. Two main radiation schemes are tested: the IFS scheme with 6 SW bands based on [8] and hlradia, the HIRLAM scheme with one SW band based on [9]. A longwave radiation study will be done later.
- Clear sky, cloud water and cloud ice cases were tested as a function of latitude, water vapour, albedo, cloud water and ice water loads and cloud water and ice effective radii.

2. Model Set-ups

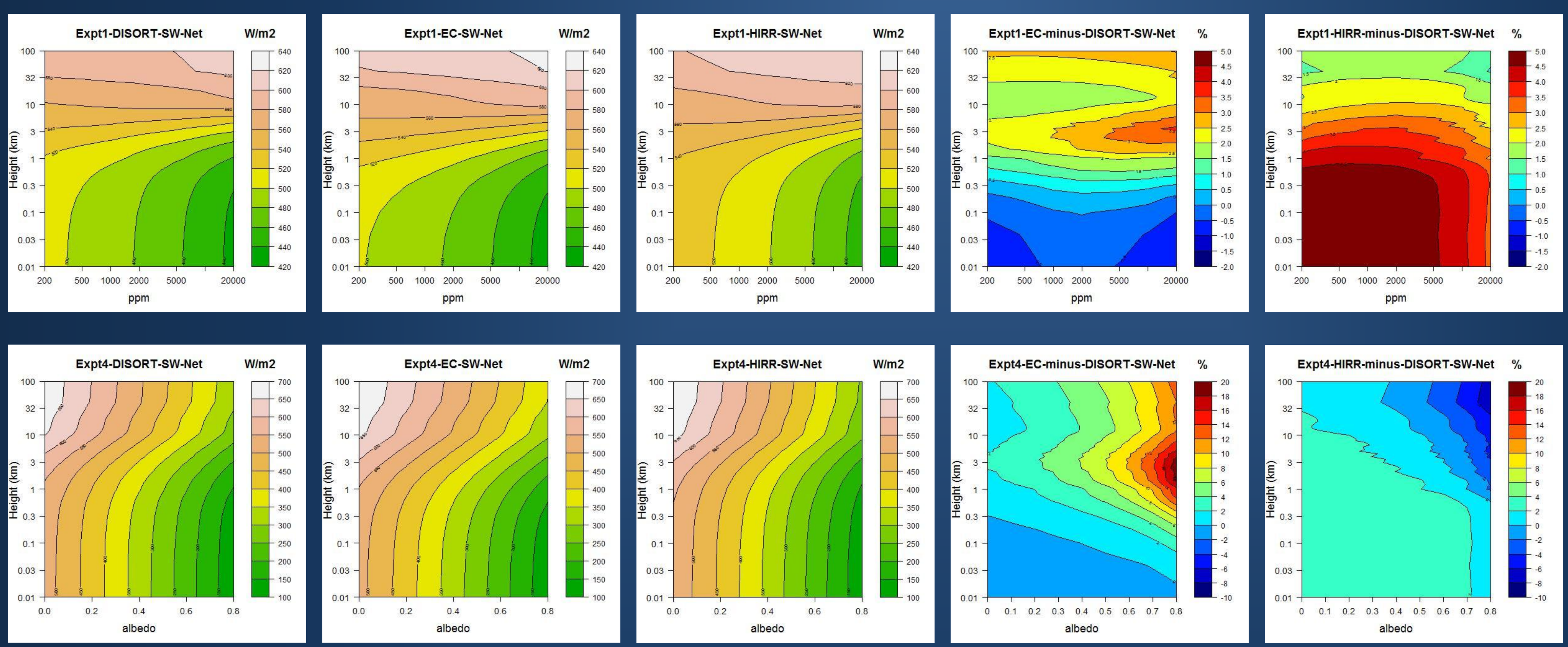
- Settings used in DISORT and MUSC unless otherwise stated: Date=March 20th (equinox), altitude=0m, solar zenith angle=56°, albedo=0.18, AFGL mid-latitude summer atmospheric profile [6].
- A 41 level atmosphere test case was used as a starting point for MUSC and modified to include the above settings.
- Only the zeroth time step is considered in MUSC and DISORT uses an angular discretisation of 30 streams.
- Within the IFS radiation scheme, Fouquart (default), Slingo and Nielsen (new and unreleased) SW parameterisations concerning cloud water are compared.

3. Clear Sky Experiments

DISORT | IFS | hlradia | IFS-DISORT (%) | hlradia-DISORT (%)

Water vapour sensitivity

Albedo sensitivity



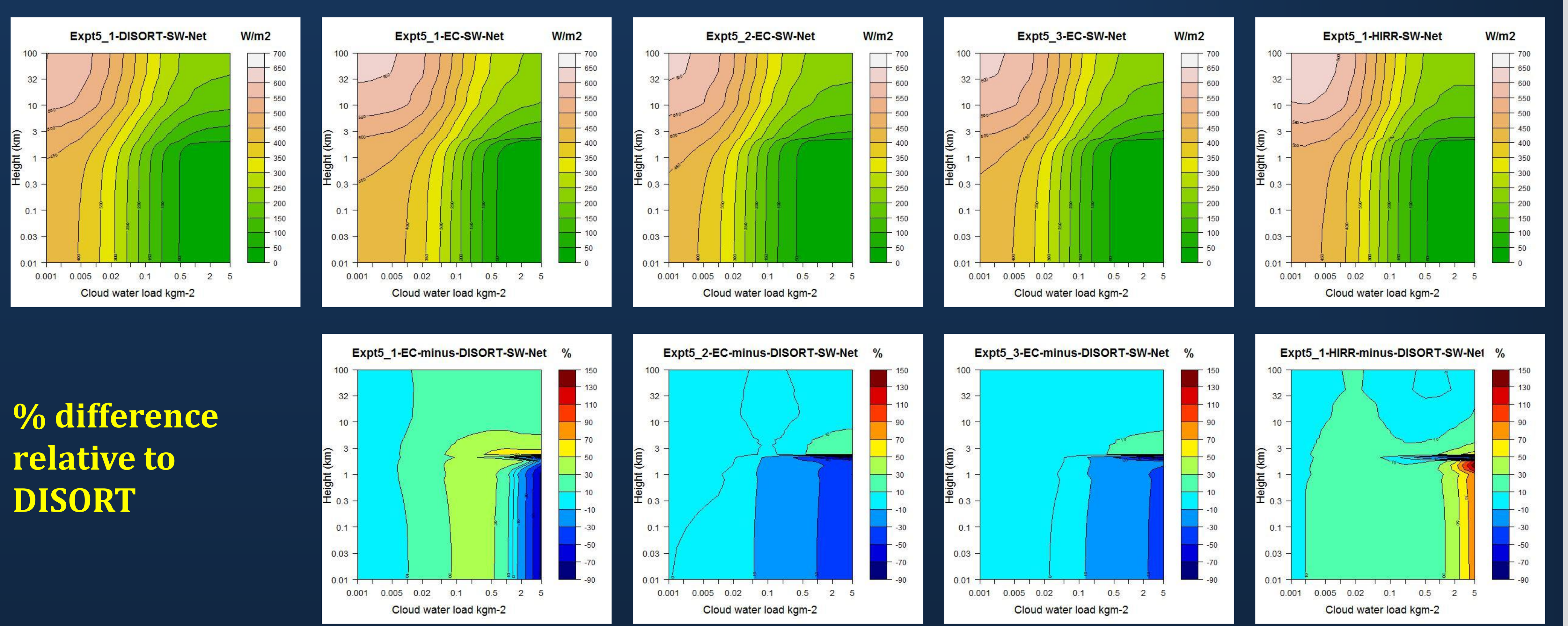
- **Water Vapour Sensitivity:** This was tested using different atmospheric water vapour profiles. The IFS scheme SW_{net} agrees with DISORT to within -2% to +4% while the hlradia scheme has a general positive bias of up to +5% at the surface.
- **Albedo Sensitivity:** The IFS scheme SW_{net} has less than 1% error at the surface and up to +20% error at around a height of 2 km for the largest surface albedos. The hlradia scheme has a surface bias of approximately +5% that becomes smaller for higher albedos and heights.

4a. Liquid Phase Clouds – Cloud Load Sensitivity

- The cloud water load was distributed evenly between 5 atmospheric layers 1-2km above the surface (and the cloud drop effective radius set to 10 µm).
- The plots show that the Fouquart (HARMONIE default) and the hlradia schemes perform worst, particularly for optically thick clouds.
- The Slingo and Nielsen schemes are much better (Nielsen scheme is the best) with % differences mostly within +/- 30%.
- The large differences below optically thick clouds are due to the fact that the absolute SW irradiances are also small.

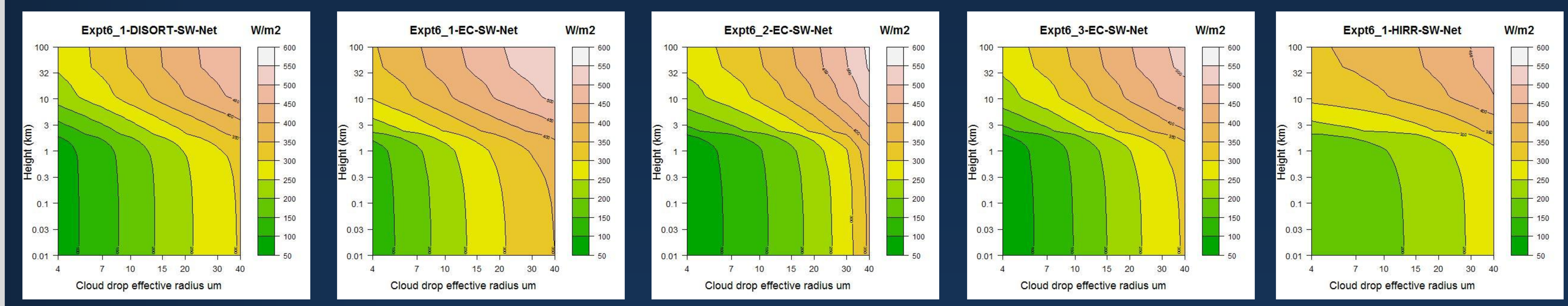
DISORT | IFS -Fouquart | IFS -Slingo | IFS -Nielsen | Hlradia

% difference relative to DISORT

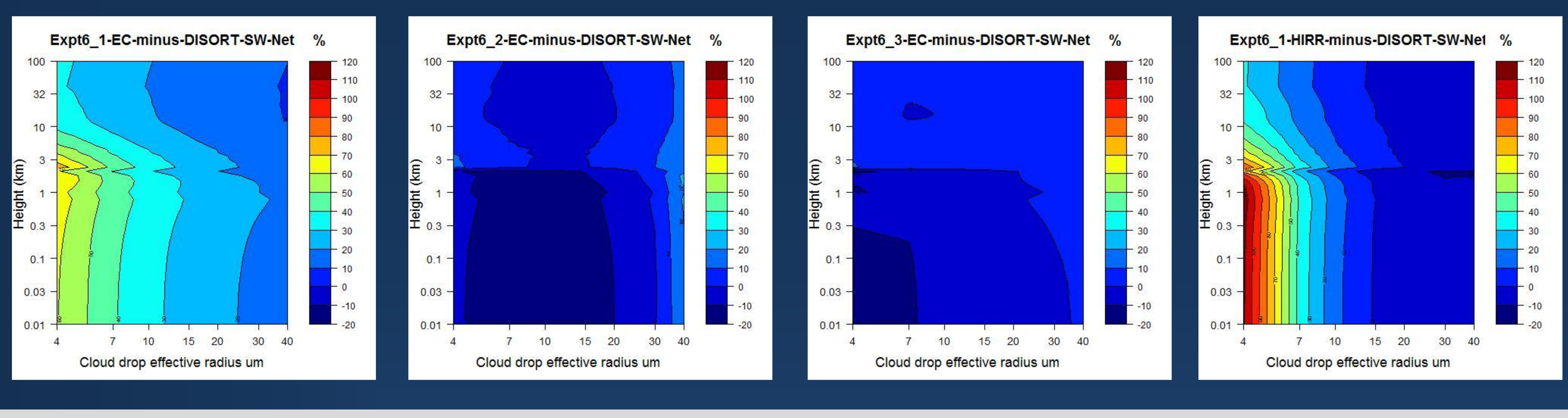


4b. Liquid Phase Clouds – Effective Radius Sensitivity

DISORT | IFS -Fouquart | IFS -Slingo | IFS -Nielsen | Hlradia



% difference relative to DISORT



- In 4a the cloud droplet effective radius was fixed at 10 µm while the cloud water load was varied. Here in 4b the cloud water load was set to 0.1 kg/m^2 and the cloud droplet effective radius was varied.
- Again the Slingo and Nielsen schemes performed best (differences within +/-20% of DISORT)
- The hlradia scheme is comparable to Slingo and Nielsen except for small cloud water effective radii while the Fouquart scheme has larger biases in all cases.

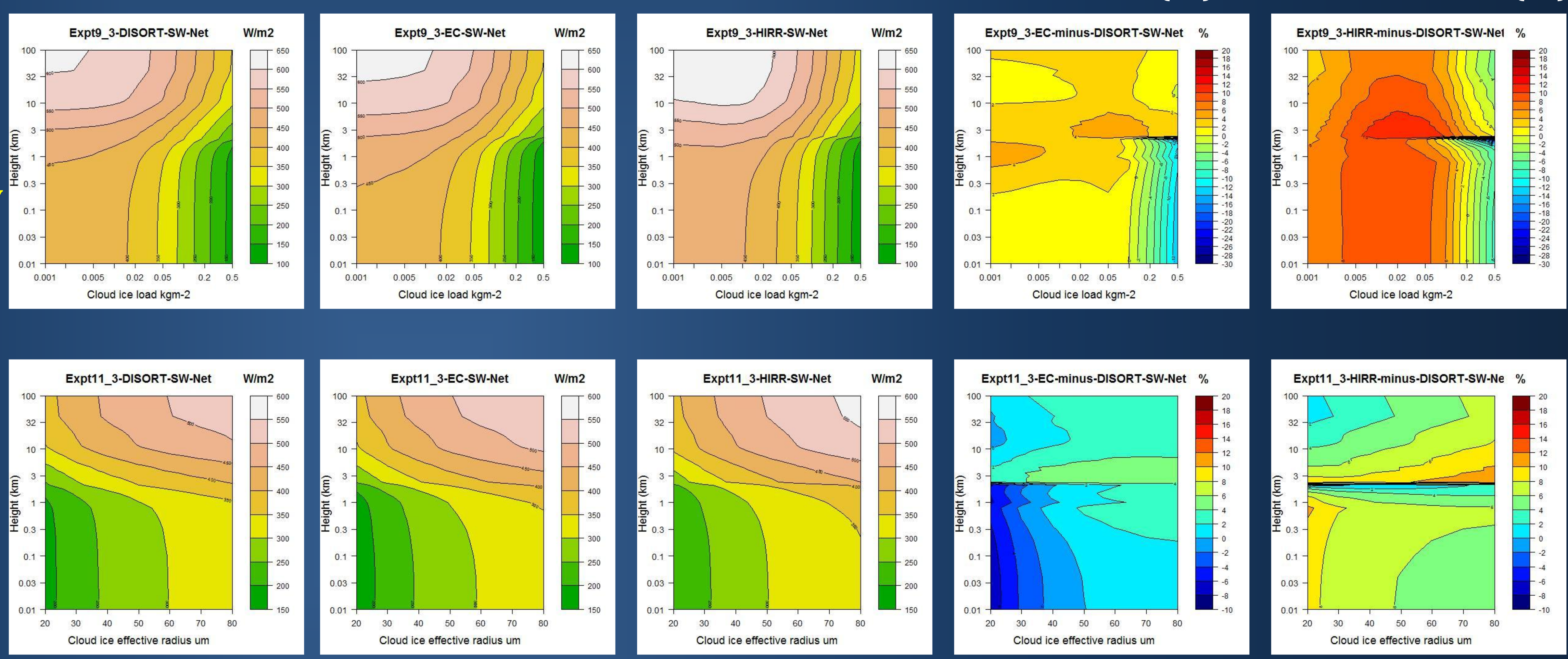
5. Ice Phase Cloud Experiments

- In the cloud ice load sensitivity experiment the effective radius was set to 50µm.
- For the effective radius test the cloud ice load was held at 0.1 kg/m^2 and distributed over 5 cloud layers between 1 and 2 km above the surface.
- In IFS and DISORT experiments cloud ice optical properties were parameterised according to Fu [4]. In hlradia ice cloud transmittance and absorptance are calculated as they are for liquid clouds [10].
- Both schemes perform very well, with ice clouds far better represented than liquid clouds.

DISORT | IFS | hlradia | IFS-DISORT (%) | hlradia-DISORT (%)

Cloud ice load sensitivity

Cloud ice effective radius sensitivity



6. Conclusions

- **Clear Sky:** Both the IFS and hlradia schemes agree very well with the DISORT model output (mostly to within a few %). In general IFS is better, except in the albedo test, particularly for high albedos. This may be due to inaccurate handling of the direct and diffuse SW radiation components.
- **Cloud Water:** Nielsen scheme matches the DISORT output best for a range of SW tests (mostly within +/-20%). The default scheme (Fouquart) in HARMONIE performs worst for average cloud water loads (~0.1 kg/m^2) and possibly should be replaced by the Nielsen or Slingo scheme.
- **Cloud Ice:** The IFS and hlradia schemes performed very well (differences mostly of the order of a few % with the IFS scheme slightly better than hlradia).

7. Next Steps

- Address the SW diffuse/direct issue in the IFS SW code.
- Improve the hlradia clear sky transmittance formula, which gives a fairly consistent bias of +4%-+6% at the surface.
- Update the hlradia cloud transmittance and absorptance formula with 2-stream expressions.
- Improve the representation of aerosols in hlradia and also in the IFS schemes.
- Test the Slingo, Nielsen and hlradia schemes operationally with HARMONIE and compare output to reliable observation data.
- Perform similar tests for longwave radiation.

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