Improved (thermal) cloud optical properties

Kristian Pagh Nielsen,
ACCORD ASW 2021-04-15

Background:

To test the theoretical background for recent KNMI empirical results regarding cloud thermal radiation interaction.

Empirical absorptance/emissivity vs LWP

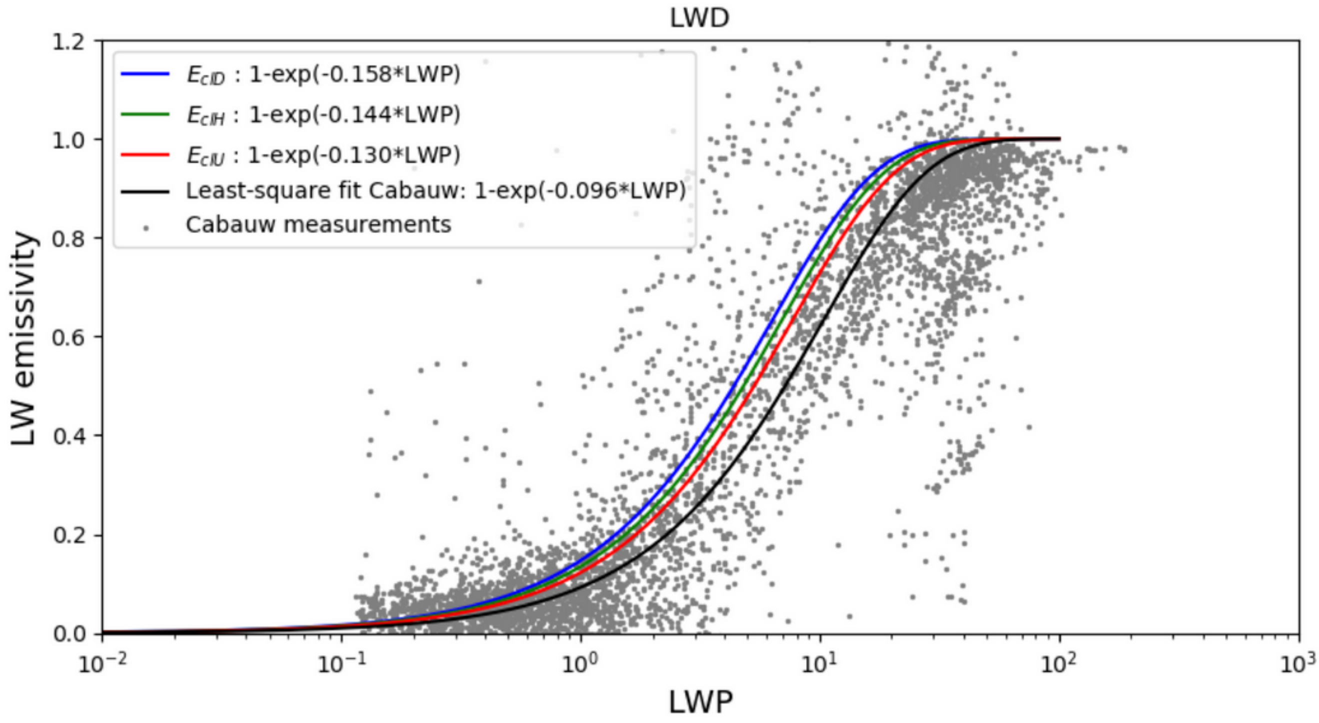


Figure 8: Emissivity/absorption as a function of cloud water path in Cabauw from 2012-2019 for all fog cases.

Band averaged absorptance/emissivity

$$\overline{\mathrm{Abs}}^{i}_{\mathrm{band}} = 1 - e^{-(1-\omega_{\mathrm{band}})\psi_{\mathrm{band}}\mathrm{LWP}} \qquad (1)$$

(Lindner & Li 2000)

ω **is the single scattering albedo**
ψ **is the mass extinction coeffiecent in** m^2/g
LWP is the liquid water path in g/m^2

Band averaged absorptance/emissivity

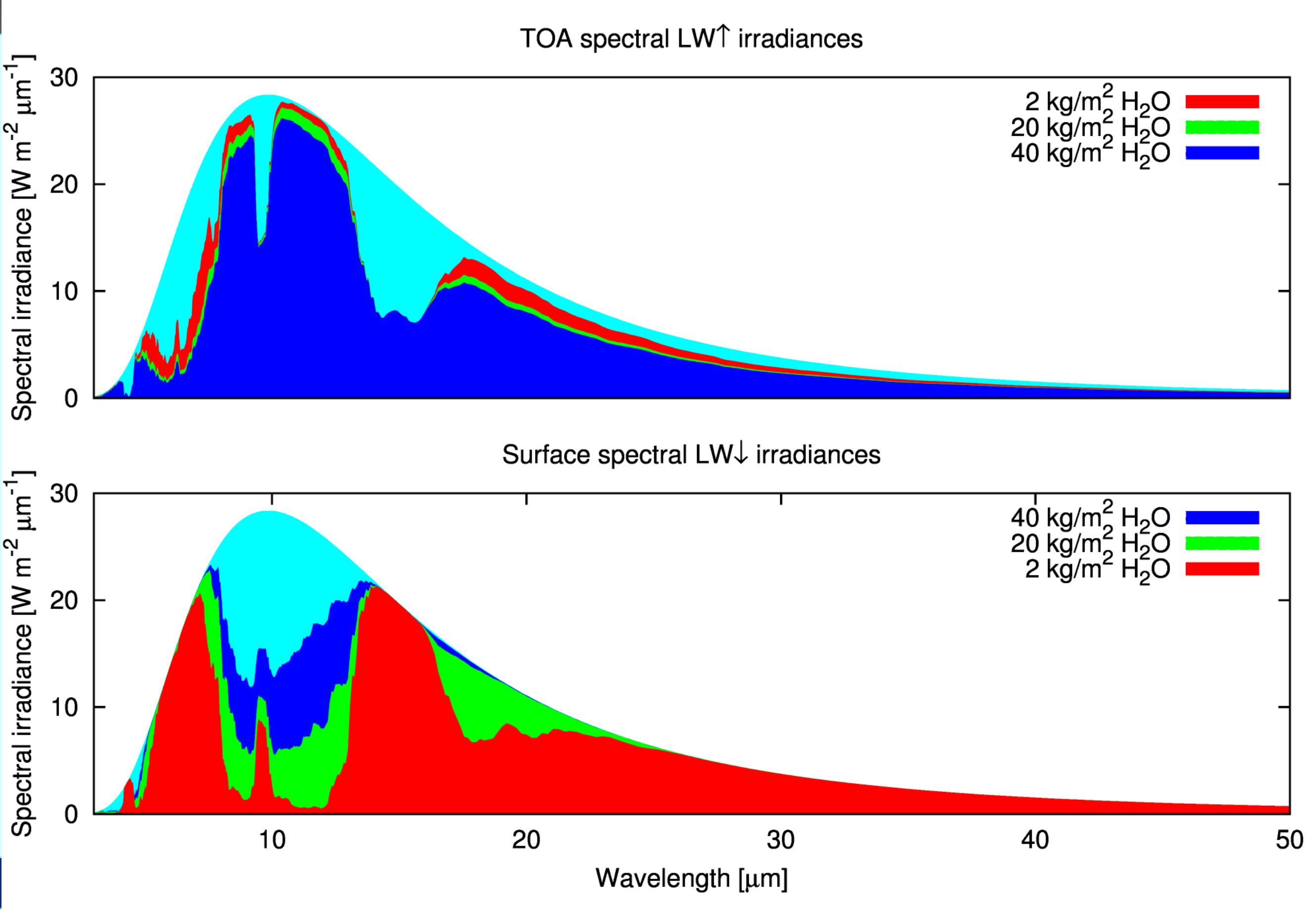
$$\overline{\mathrm{Abs}}^{i}_{\mathrm{band}} = 1 - e^{-(1-\omega_{\mathrm{band}})\psi_{\mathrm{band}}\mathrm{LWP}} \qquad (1)$$

(Lindner & Li 2000)

ω is the single scattering albedo
ψ is the mass extinction coeffiecent in m^2/g
LWP is the liquid water path in g/m^2

When LW scattering is not considered, there is no need to account for all three optical properties (τ, ω & g)!

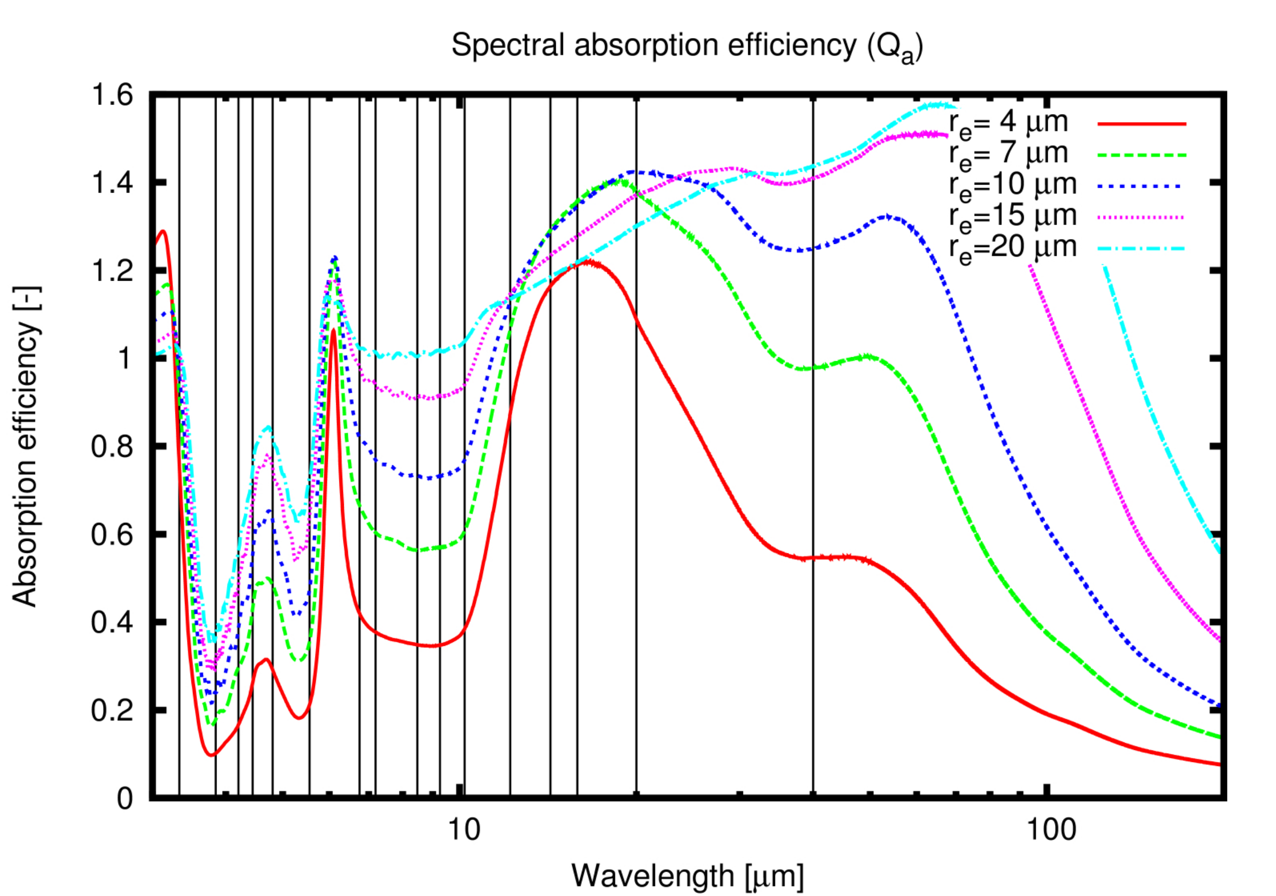
Spectrally resolved atmospheric thermal (LW) radiation



DMI

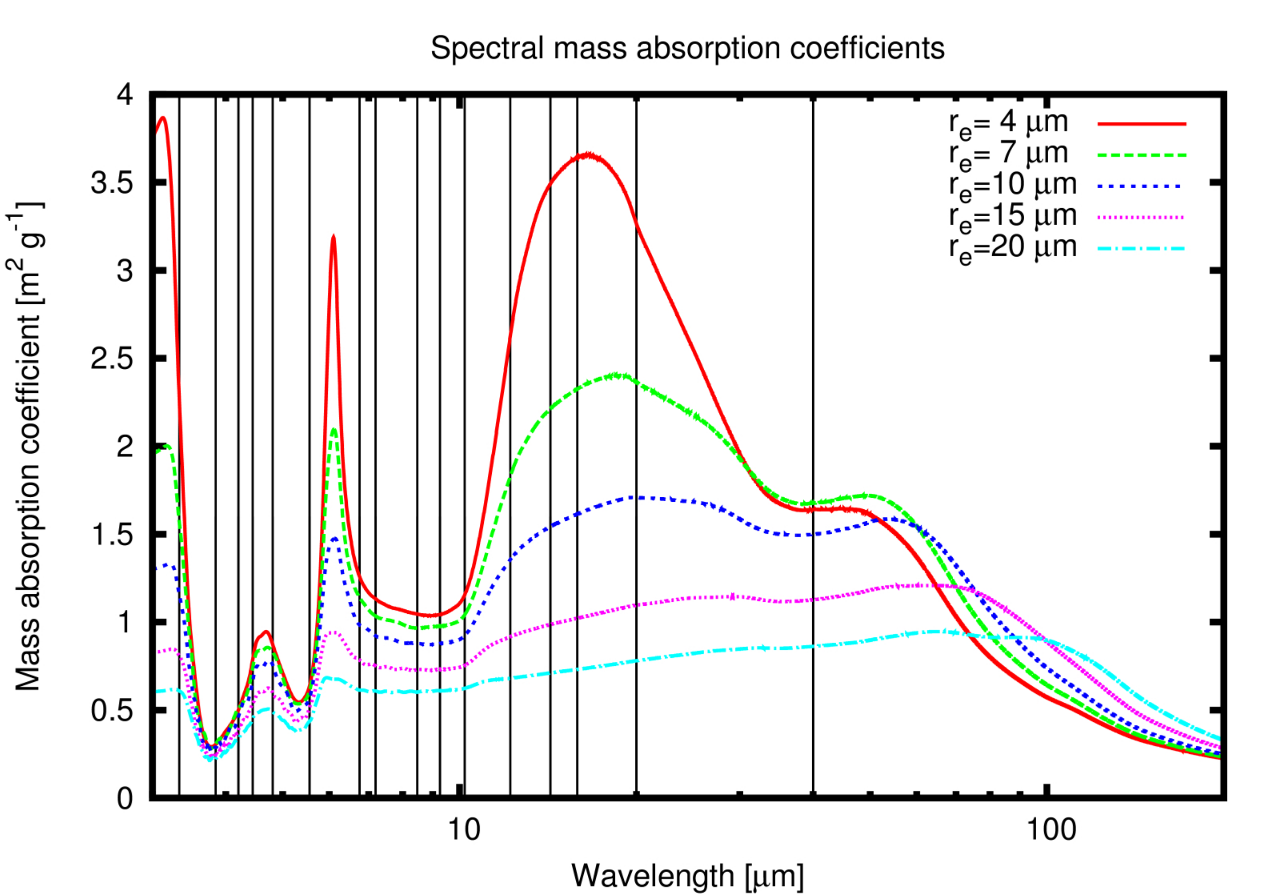
ACCORD

Mie computations of LW cloud-radiation interactions



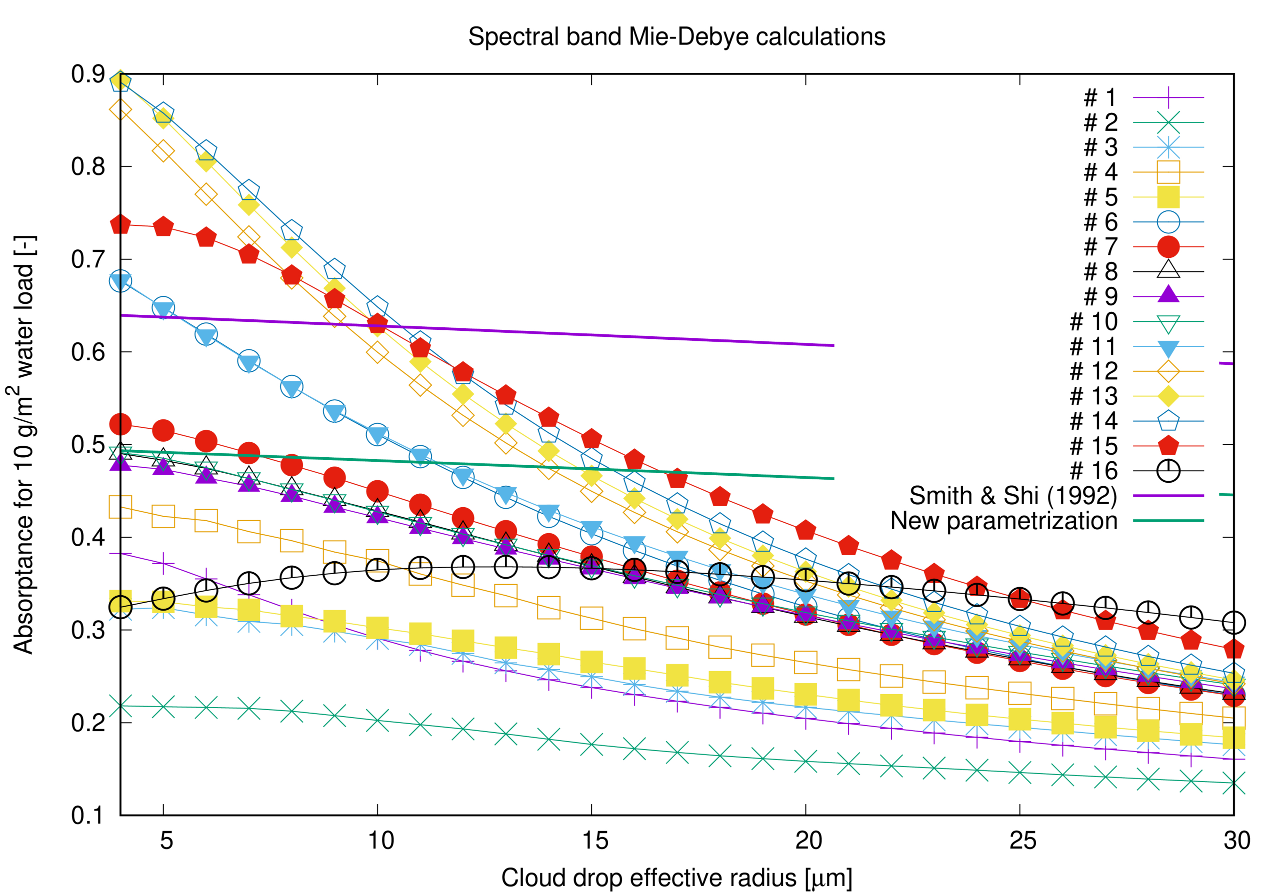
(Mie 1908; Wiscombe 1980). The lines mark 16 LW spectral bands.

Mie computations of LW cloud-radiation interactions



(Mie 1908; Wiscombe 1980). The lines mark 16 LW spectral bands.

Spectral absorptance/emissivity for LWP = 10 g/m^2



Parametrization

```
...
DO JRTM=1,16
  DO JL = KIDIA,KFDIA
    ...
    ! water cloud spectral emissivity a la Nielsen (2020)
    Z1RADL = 1.0_JPRB / ZRADLP(JL)
    ZRSALD = RKPNLWCA(JRTM,1) + RKPNLWCA(JRTM,2)*ZRADLP(JL) + &
     &       RKPNLWCA(JRTM,3)*ZRADLP(JL)*ZRADLP(JL) + &
     &       RKPNLWCA(JRTM,4)*ZRADLP(JL)*ZRADLP(JL)*ZRADLP(JL) + &
     &       RKPNLWCA(JRTM,5)*Z1RADL + &
     &       RKPNLWCA(JRTM,6)*Z1RADL*Z1RADL + &
     &       RKPNLWCA(JRTM,7)*Z1RADL*Z1RADL*Z1RADL
    ...
    ZTAUCLD(JL,JK,JRTM) = ZRSALD*ZFLWP(JL)+ZRSAID*ZFIWP(JL)
    ...
  ENDDO
ENDDO
...
```

DMI

ACCORD

Part conclusion:

- Theoretical analyses confirms that the current HARMONIE-AROME LW cloud emissivity is too high.
- The spectrally resolved LW cloud emissivity should be accounted for.

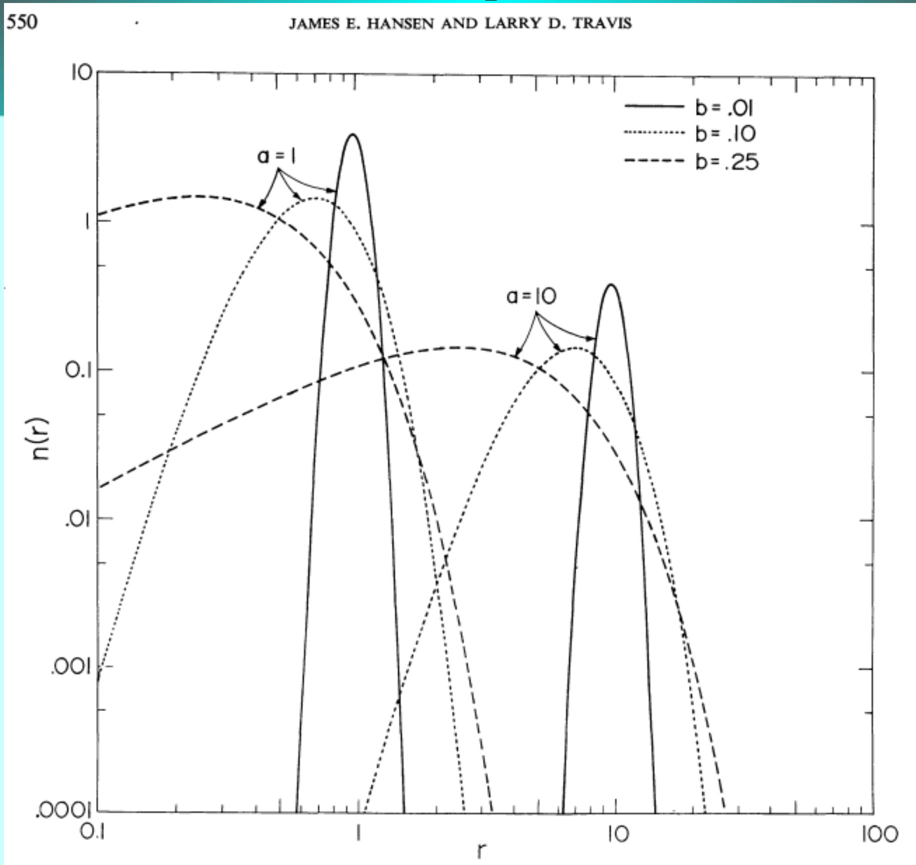
Question about cloud r_e limits

Karl-Ivar Ivarsson (2021-04-06): ”***Perhaps one has to use less strict limits of the effective radius?***”

```
.../phys_radi/radlsw.F90:

        ZRADLP(JL)=MAX(ZRADLP(JL), 4.0_JPRB)
        ZRADLP(JL)=MIN(ZRADLP(JL),16.0_JPRB)

.../phys_radi/radlswr.F90:

        ZRADLP(JL)=MAX(ZRADLP(JL), 4.0_JPRB)
        ZRADLP(JL)=MIN(ZRADLP(JL),30.0_JPRB)
```

Unit = μm

The effect of cloud droplet size distribution



a: Effective radius r_e. b: Distribution spread ν_e. Hansen and Travis (1974). Ongoing Meteo France PhD project by Erfan Jahangir on introducing this effect.

DMI

ACCORD

Concluding remarks:

- Theoretically improved spectral LW liquid cloud optical properties have been developed for the radiation scheme, which agrees with recent empirical results by Kettler et al.

- For Danish fog test cases reducing the CDNC to 50 cm^{-3} in general reduces for overforecasting. The new LW optical properties help further.

- A multi-institute benchmarking study of cloud optical properties is recommended.

Contact details: kpn@dmi.dk

DMI

ACCORD