ecRad in ICON: Recent progress

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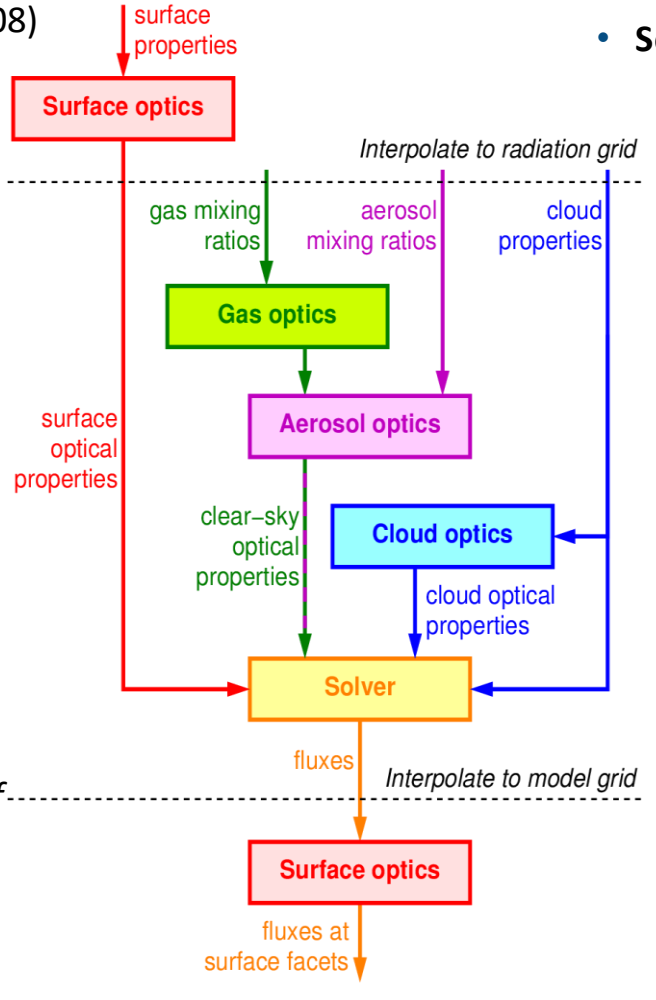
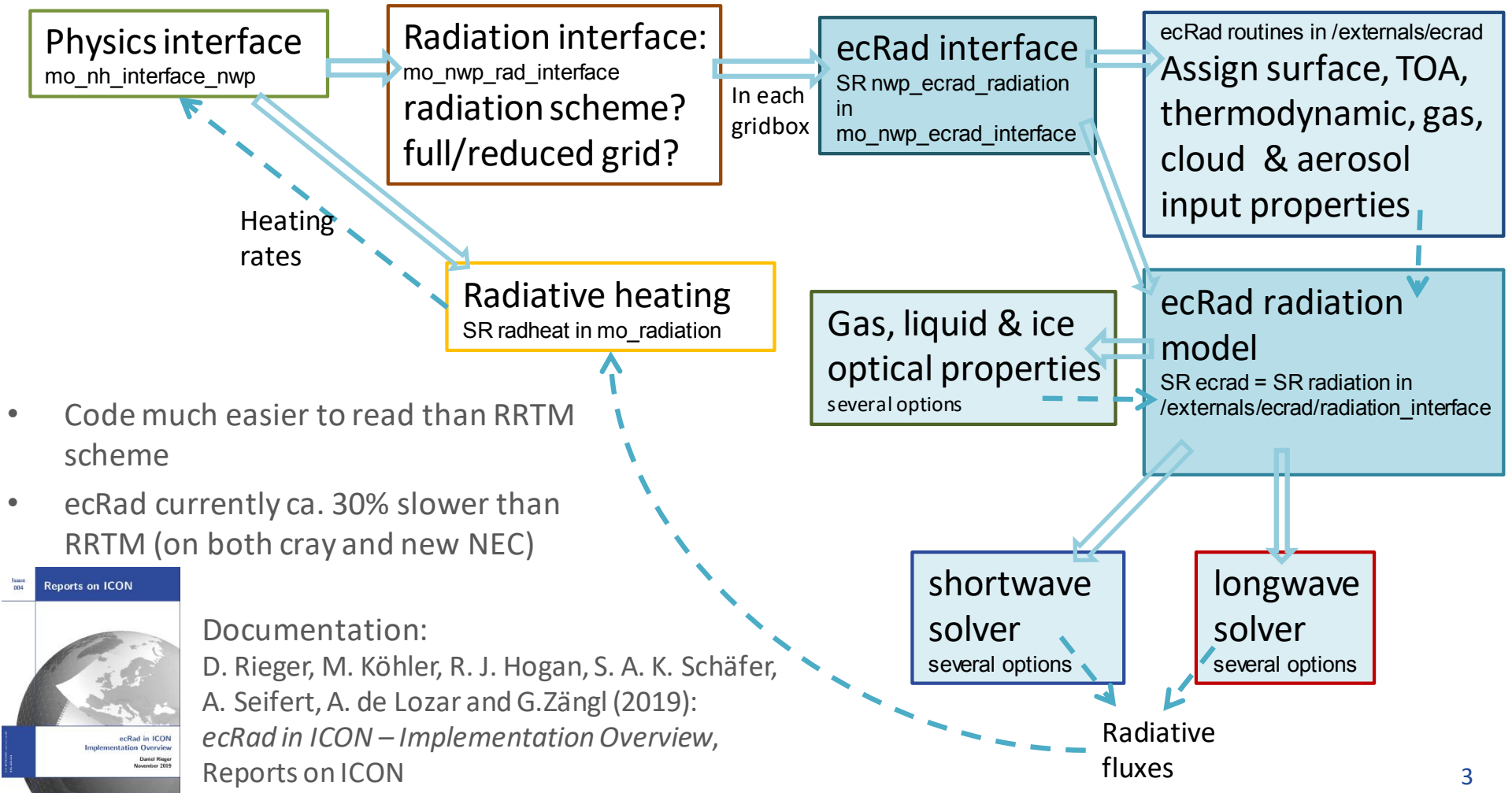
New modular radiation scheme: ecRad (Hogan & Bozzo, 2018)

- **Gas optics:** RRTMG (Iacono et al. 2008)
  - *Plan to develop new scheme with fewer spectral intervals*
- **Aerosol optics:** variable species number and properties (set at run-time)
- **Cloud optics:**
  - **liquid:** SOCRATES (MetOffice), Slingo (1989)
  - **ice:** Fu 1996, 1998 (default), Yi et al. 2013 or Baran et al. 2014
- *Surface (under development)*
  Rigorous and consistent treatment of urban and forest canopies



- **Solvers** for radiative transfer equations:
  - **McICA** (Pincus et al. 2005), **Tripleclouds** (Shonk & Hogan, 2008) or **SPARTACUS** (Schäfer et al. 2016, Hogan et al. 2016)
  - SPARTACUS makes ecRad the only global radiation scheme that can do **3D** radiative effects
  - Longwave scattering optional
  - Can configure **cloud overlap**
  - **Cloud inhomogeneity**: can configure width and shape of PDF

ecRad in ICON (implemented by Daniel Rieger)



- Code much easier to read than RRTM scheme
- ecRad currently ca. 30% slower than RRTM (on both cray and new NEC)

Documentation:
D. Rieger, M. Köhler, R. J. Hogan, S. A. K. Schäfer, A. Seifert, A. de Lozar and G.Zängl (2019): *ecRad in ICON – Implementation Overview*, Reports on ICON

Using ecRad in ICON

To use ecRad, **need to specify** in configure: ./configure --enable-ecrad

+ in ICON namelist:

```
&nwp_phy_nml
inwp_radiation = 4                    ! 0: no radiation, 1: RRTM, 2: RG, 3: PSRAD, 4: ecRad
&radiation_nml
ecRad_data_path = '<ICON-directory>/externals/ecrad/data'
```

Can configure model behaviour:

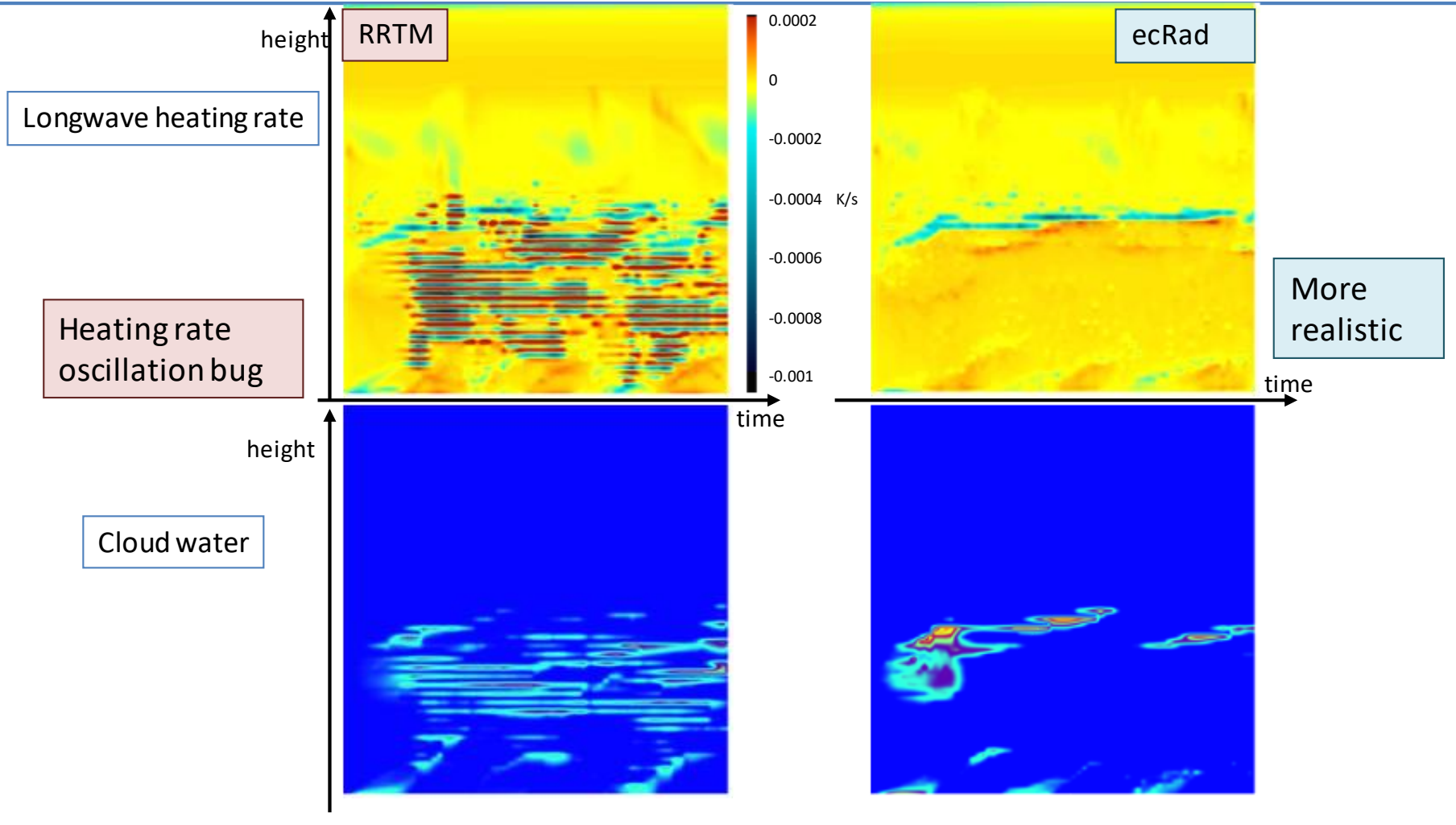
```
&radiation_nml
icld_overlap=2                        ! Cloud overlap (in RRTM only changes sw); 1: maximum-random, 2: exponential-
                                        random, 3: maximum, 4: random
irad_aero = 0                         ! Aerosols; 0: no aerosol, 2: constant, 5:Tanre climatology, 6: Tegen climatology
iliquid_scat = 0                      ! Liquid optics scheme:  0: SOCRATES, 1: Slingo (1989)
iice_scat = 0                         ! Ice optics scheme:  0: Fu et al. (1996), 1: Baran et al. (2016)
llw_cloud_scat  = .true.              ! Do longwave cloud scattering?                                    etc.
```

Additional ecRad namelist parameters set in SR setup_ecrad in mo_nwp_ecrad_init

```
ecrad_conf%i_solver_sw            = ISolverMcICA   ! Short-wave solver
ecrad_conf%i_solver_lw            = ISolverMcICA   ! Long-wave solver
ecrad_conf%do_3d_effect           = .false.        ! Do we include 3D effects?
ecrad_conf%do_lw_aerosol_scattering  = .false.     ! LW scattering due to aerosol                    etc.
```

Not all combinations possible. ecRad documentation at https://confluence.ecmwf.int/display/ECRAD

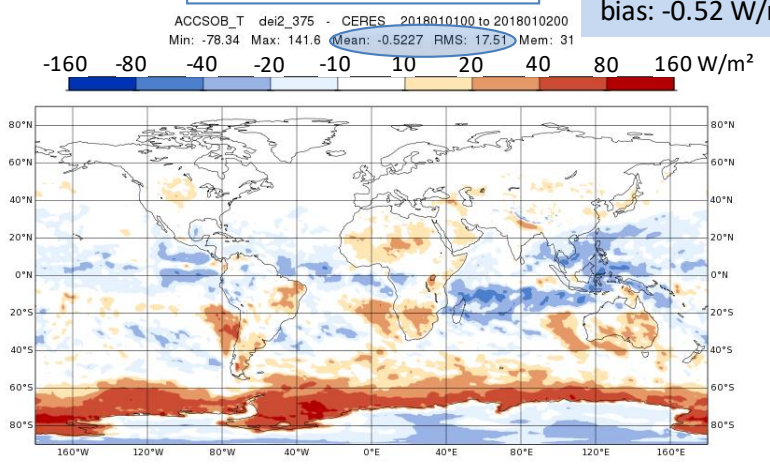
ecRad versus RRTM : ICON single column model



Evaluation (CERES): ecRad vs. RRTM, 24h forecasts, January 2018

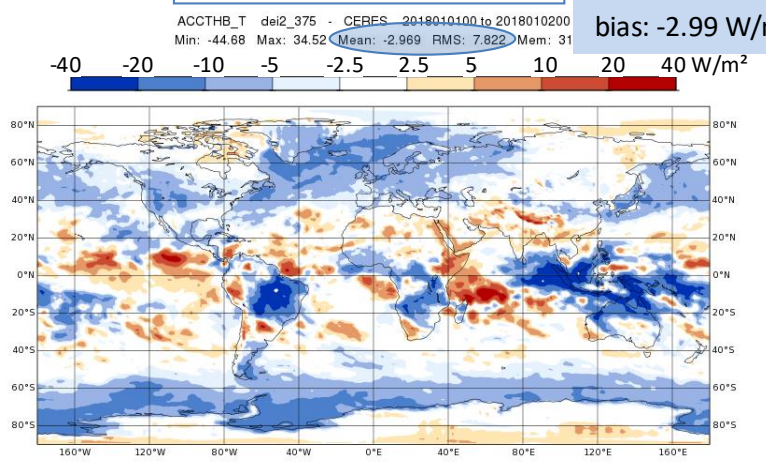
TOA solar vs. CERES

bias: -0.52 W/m²



TOA thermal vs. CERES

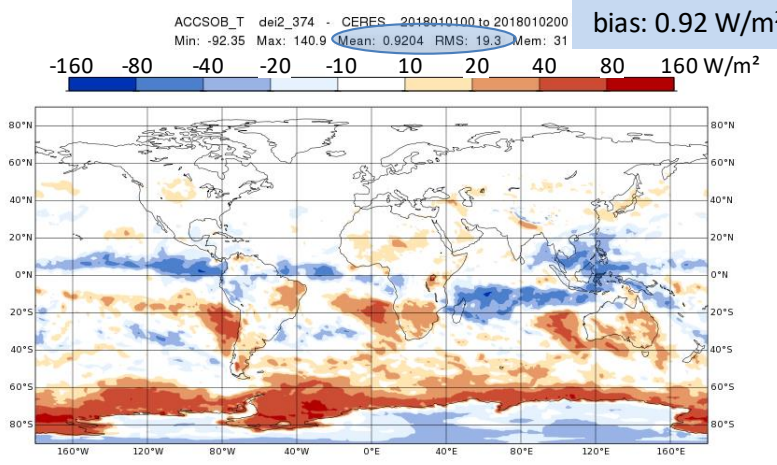
bias: -2.99 W/m²



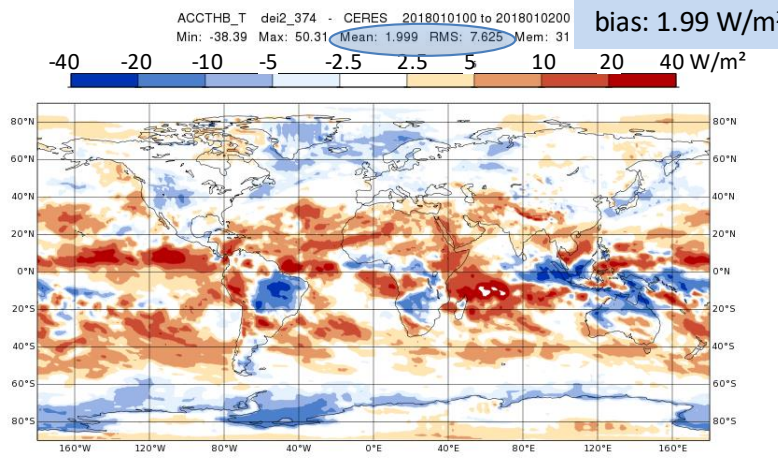
ecRad

RRTM

bias: 0.92 W/m²



bias: 1.99 W/m²



Radiative differences: ecRad - RRTM

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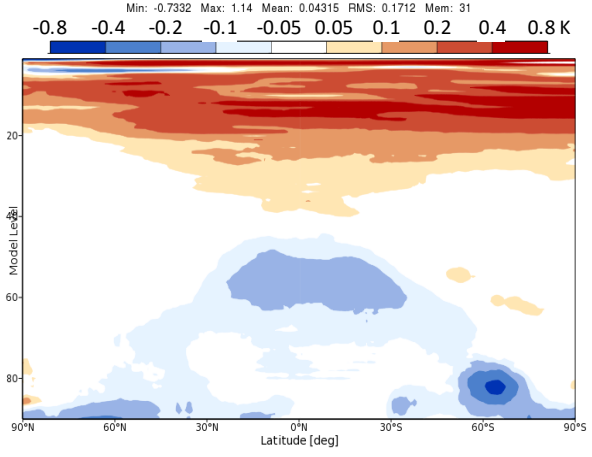
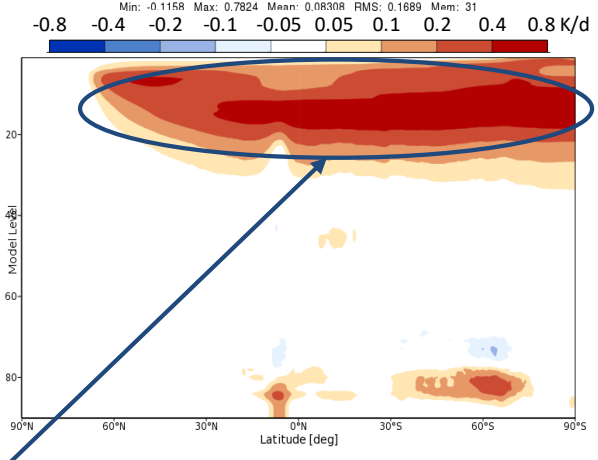
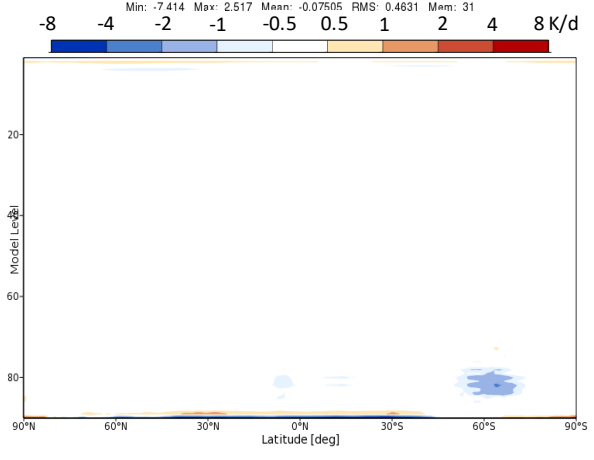


T SW tendency

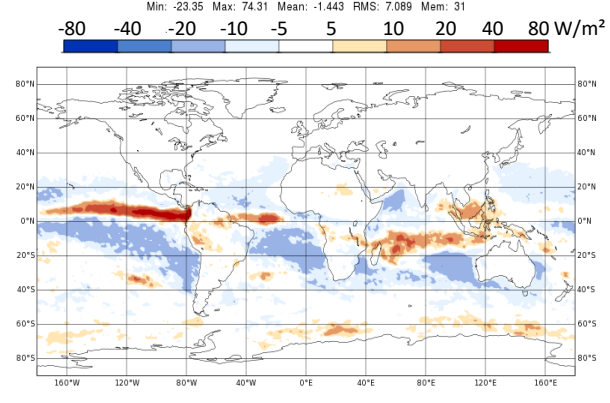


T LW tendency

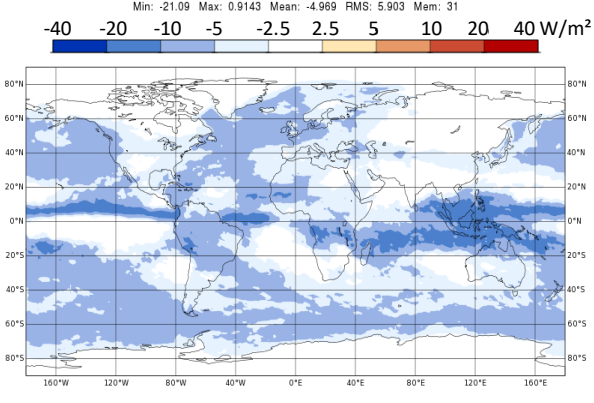


Stratospheric shortwave heating stronger in ecRad

SW TOA flux

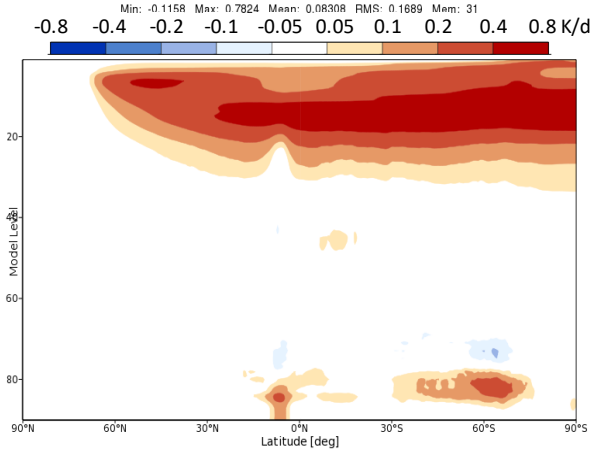


LW TOA flux

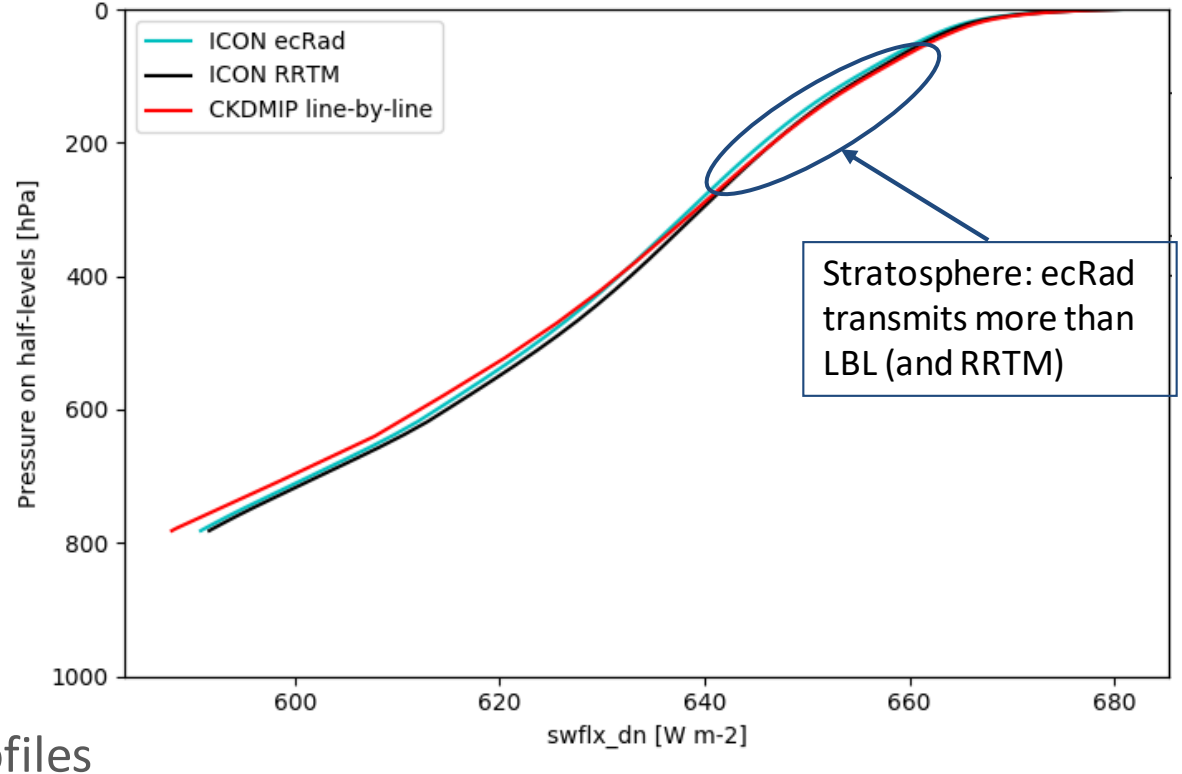


Stratospheric heating in ecRad

Global ICON: T SW tendency



Compare ICON SCM to line-by-line results:



Heating difference due to optical properties or solver?

→ Check optical property profiles

ecRad LW cloud scattering ON - OFF

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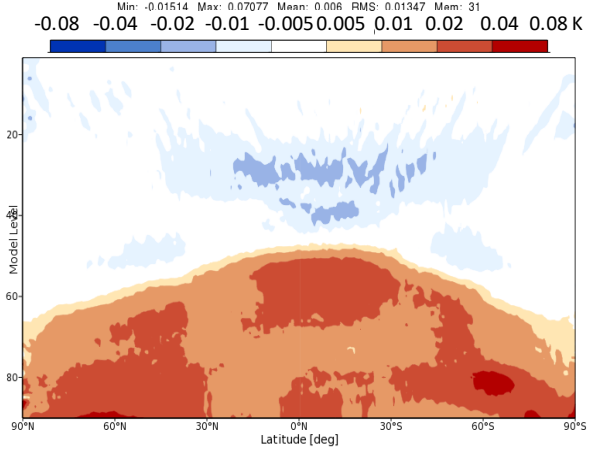
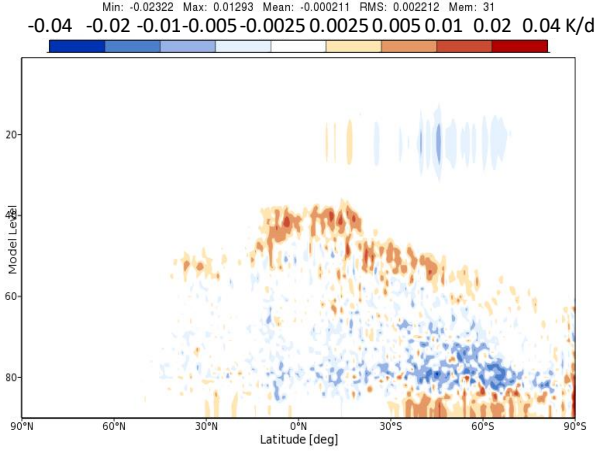
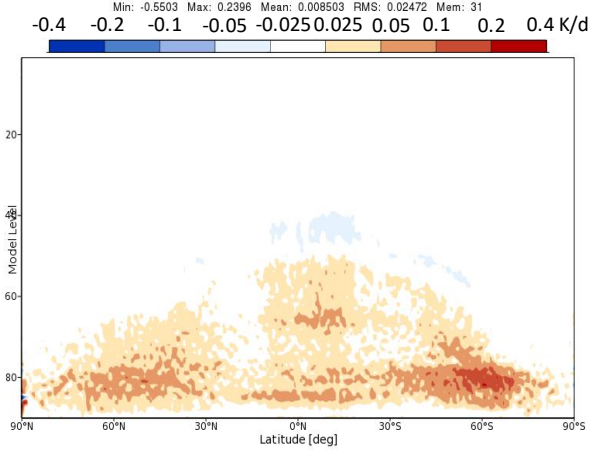


T SW tendency

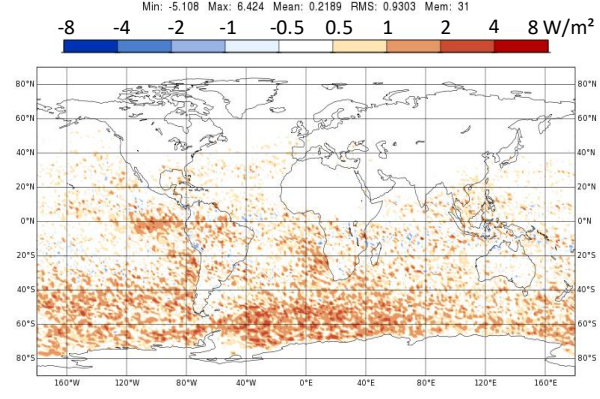


T LW tendency

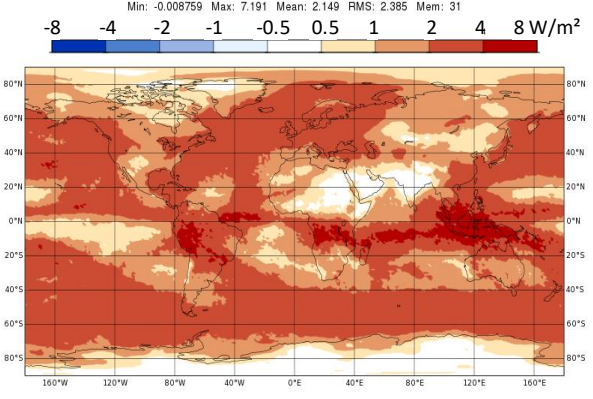


Longwave scattering slightly warms atmosphere

SW TOA flux



LW TOA flux



Differences ecRad - RRTM: Cloud feedbacks

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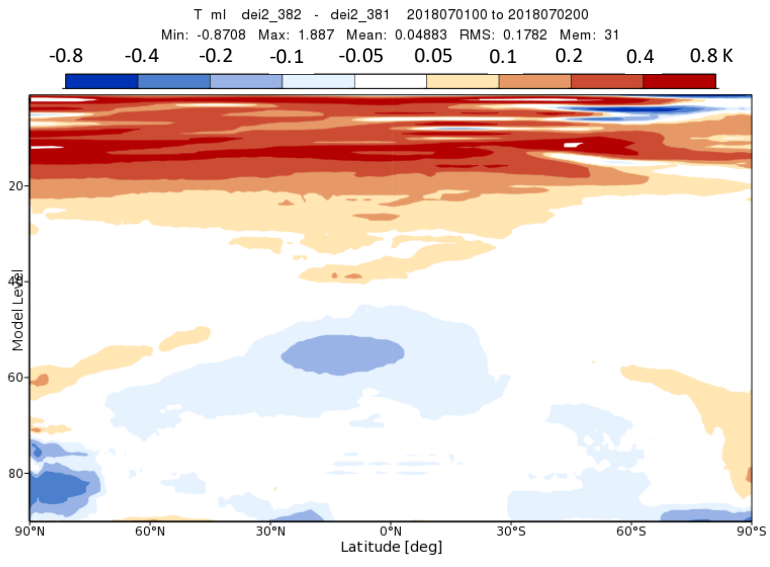
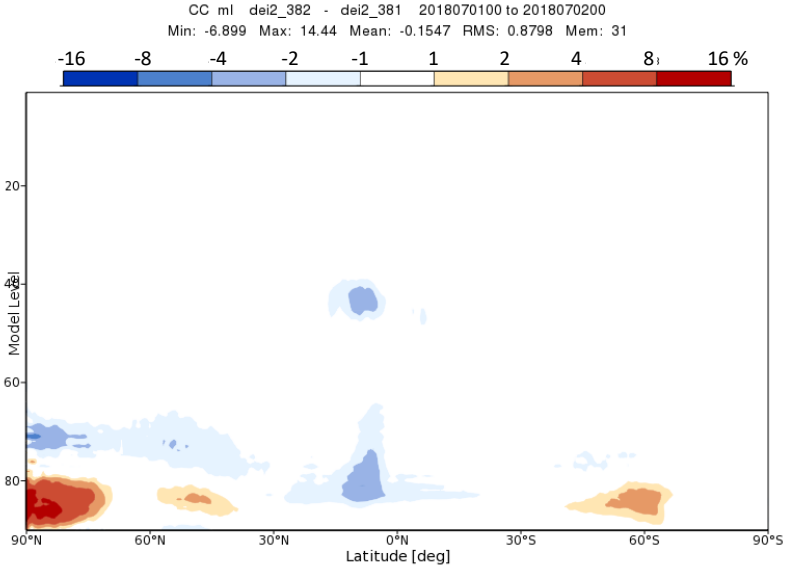


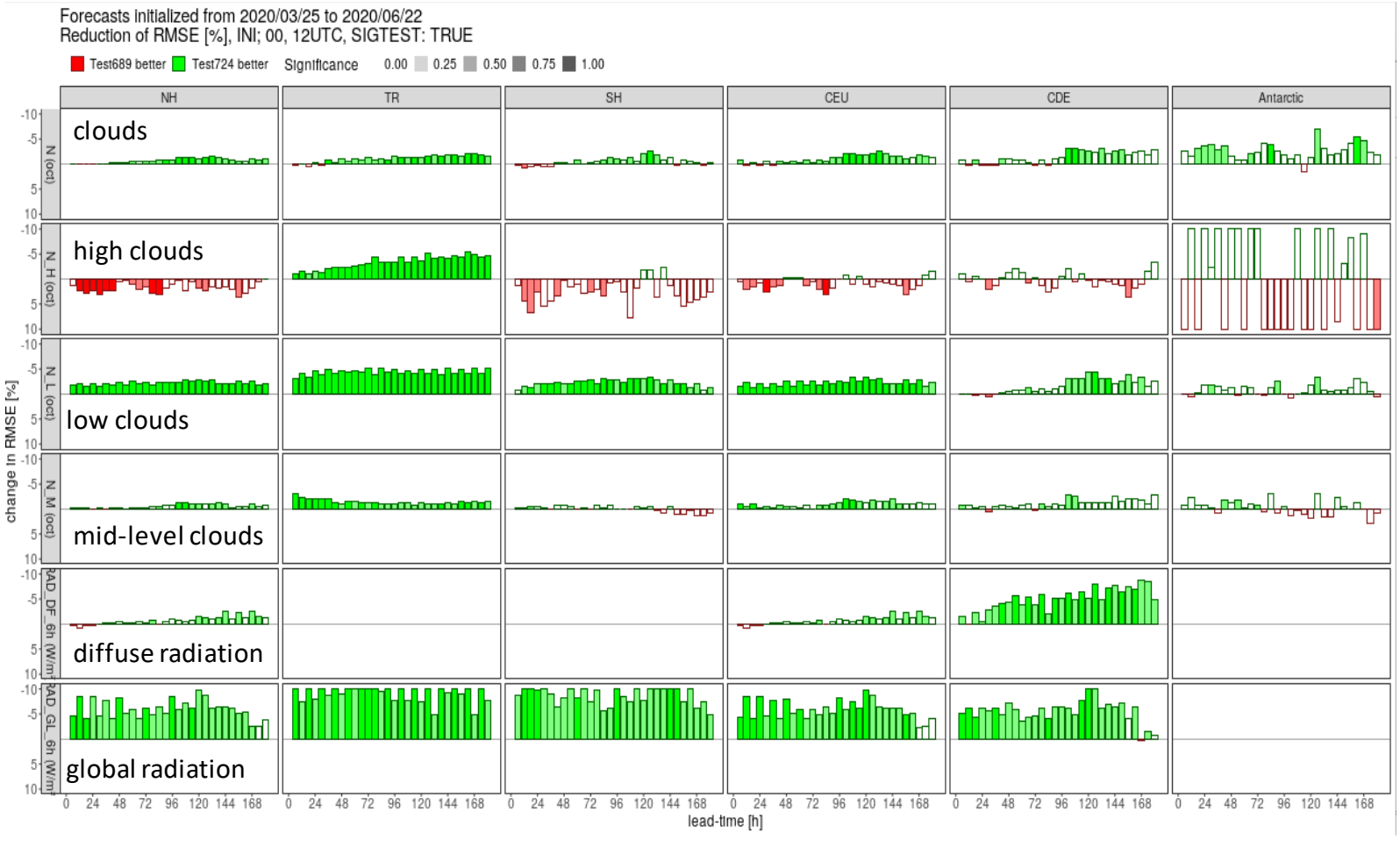
Cloud cover



- Clouds optically thinner in ecRad → cooler at cloud base, warmer at cloud top
  → More cloud at base, less cloud at top
- Less high/tropical cloud – due to removal of oscillating heating rate bug?

Global ICON: fixed turbulence bug + ecRad improve troposphere

Scorecard BaCy-Expt. 25.03. – 15.06.2020: Clouds and radiation (by G. Zängl)



Tuning ongoing

ice optics: Baran - Fu

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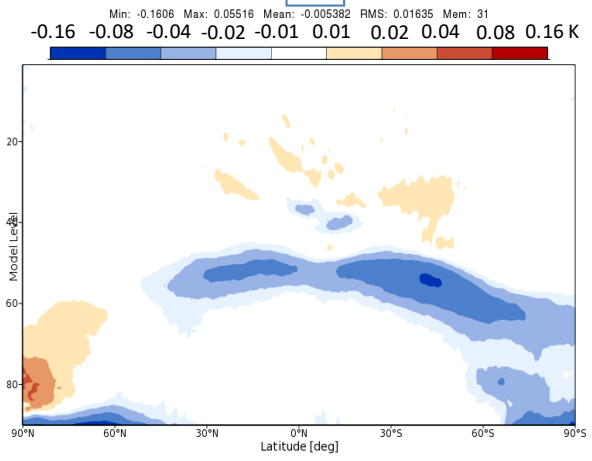
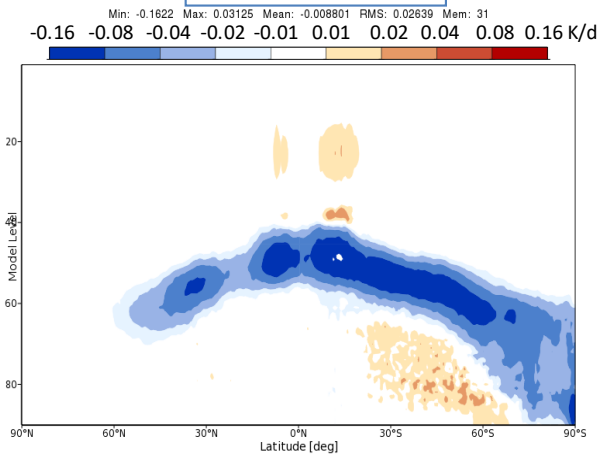
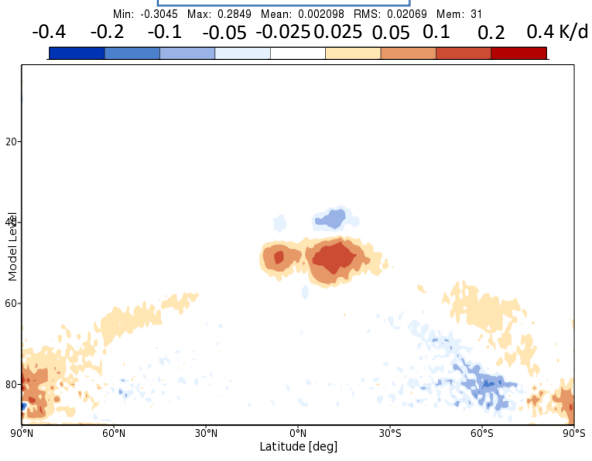


T SW tendency

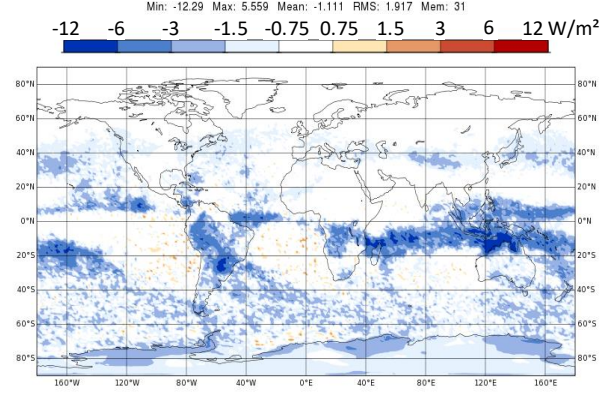


T LW tendency

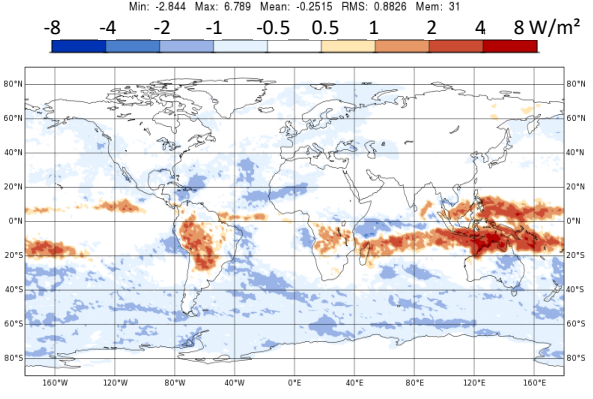


Considerable uncertainty in ice optics assumptions

SW TOA flux

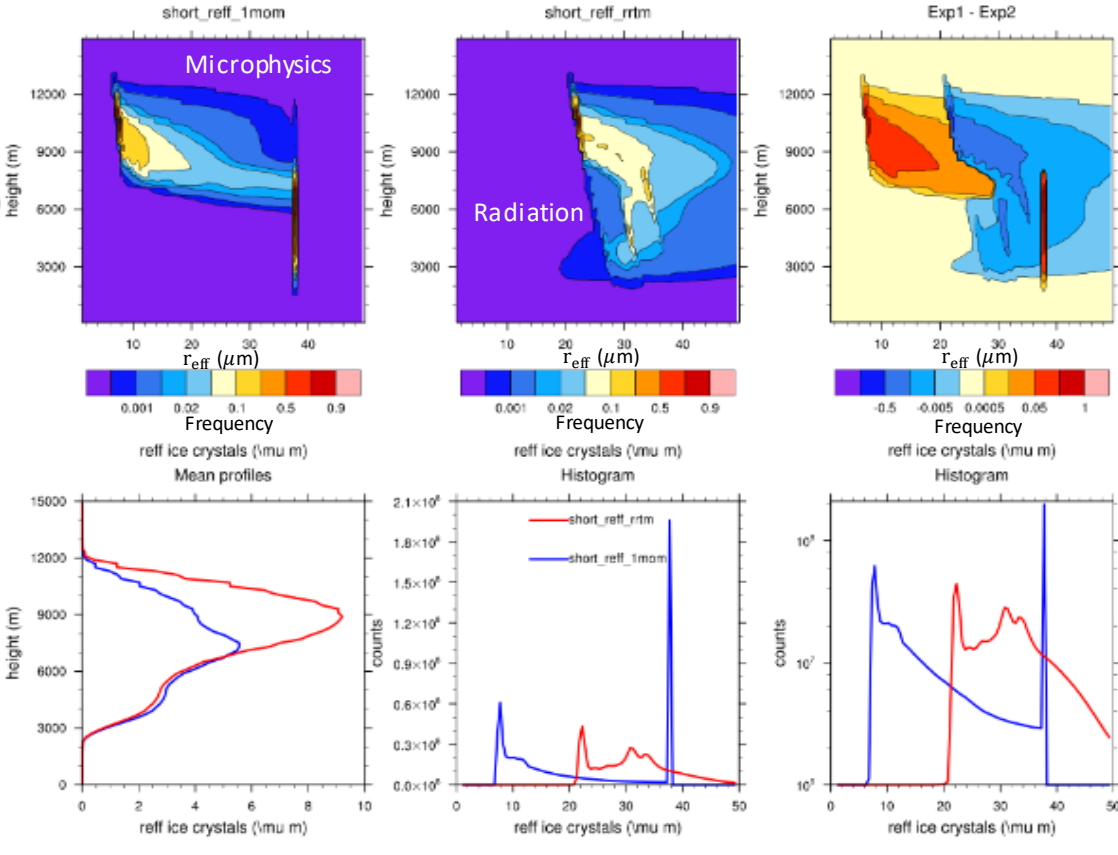


LW TOA flux



Input: cloud particle effective radius

- Calculated from cloud water, needs knowledge or assumptions on cloud particle size distribution and geometry
- Important for radiation (small particles dominate radiative effect)
- **Currently**: ice effective radius for radiation **inconsistent** with microphysics (liquid water better)
- Alberto de Lozar uses 1-moment- and 2-moment-microphysics assumptions to calculate effective radius for radiation
  → test radiation effect



Plots by A. de Lozar

Summary

- **ecRad implemented in ICON** (D. Rieger), planned: operational early 2021
- **ecRad improves results in troposphere**, removes double ITCZ; stratospheric warm bias: tunable, ongoing analysis
- **Choices for ice and water optics and radiation solver**; ecRad represents **cloud inhomogeneity,** SPARTACUS solver can parametrise sub-grid **3D** obstacles. Modular scheme allows uncertainty estimation.

Ongoing and future work:

- Evaluation of ecRad in ICON (with G. Zängl, PP CAIIR, R. Hogan and C. Klinger)
- Generalise ecRad to user-defined number of cloud particle species (with R. Hogan at ECMWF; planned for autumn 2020)
- Extend ice optics to larger ice particles like snow or graupel (with R. Hogan, U. Blahak and PP CAIIR)
- Cloud particle effective radius parametrisation consistent with microphysics (A. de Lozar)
- Extended correction for 3D surface structure, similar to COSMO (MeteoSwiss)
- Improved treatment of surface emissivity (B. Fay)

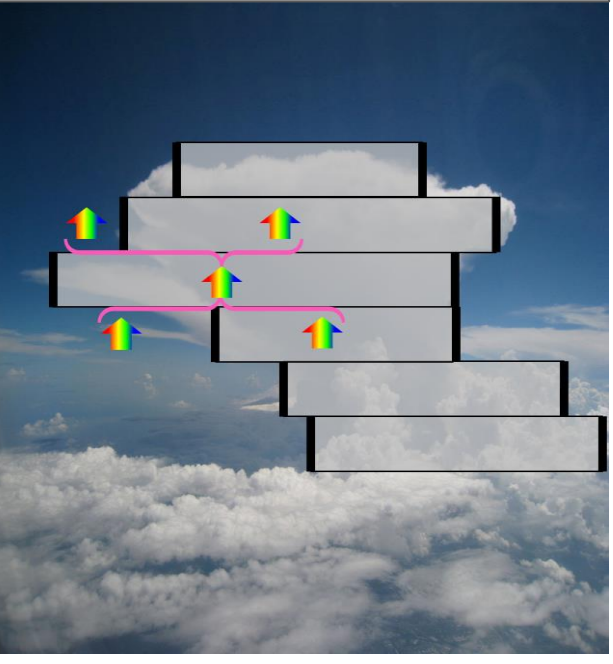
Thank you for your attention!

Contact: sophia.schaefer@dwd.de

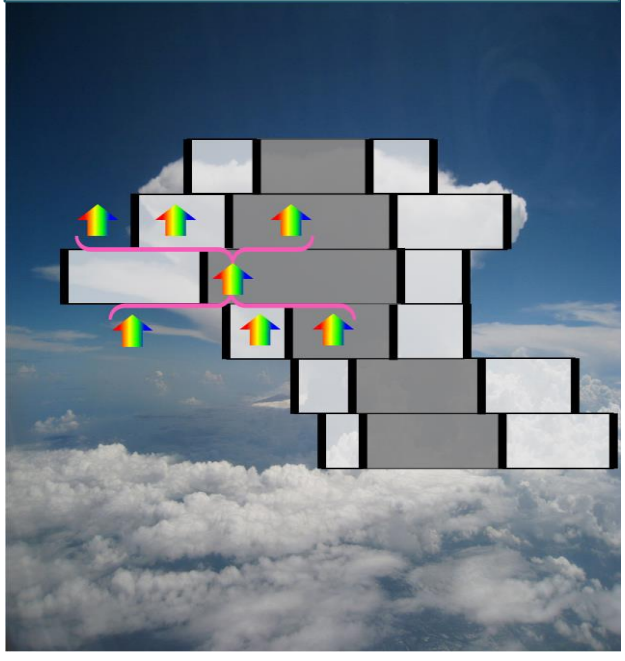
Radiation solvers

All solvers for global models **simplify** by treating **only vertical** dimension explicitly.

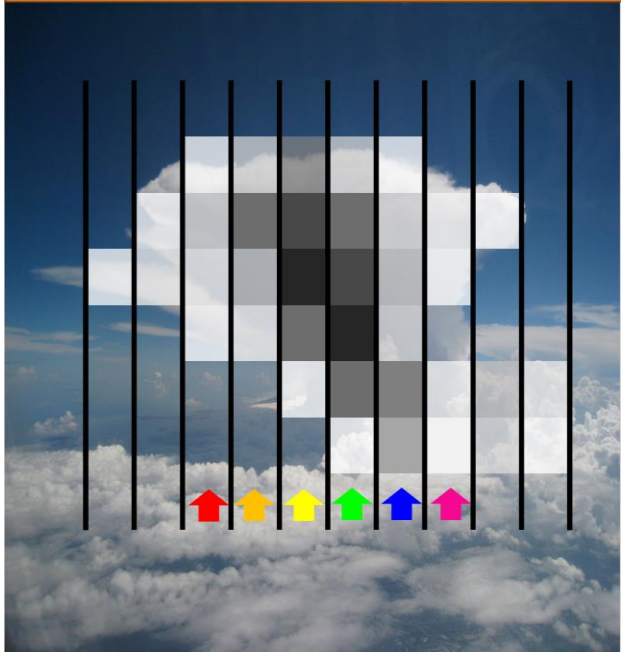
Two-stream solver: solve in **cloudy / clear regions**, partition at layer boundaries according to **overlap** (e.g. RRTM in ICON)



Tripleclouds/SPARTACUS: similar; 3 regions: **clear, thin cloud, thick cloud** → cloud **inhomogeneity**



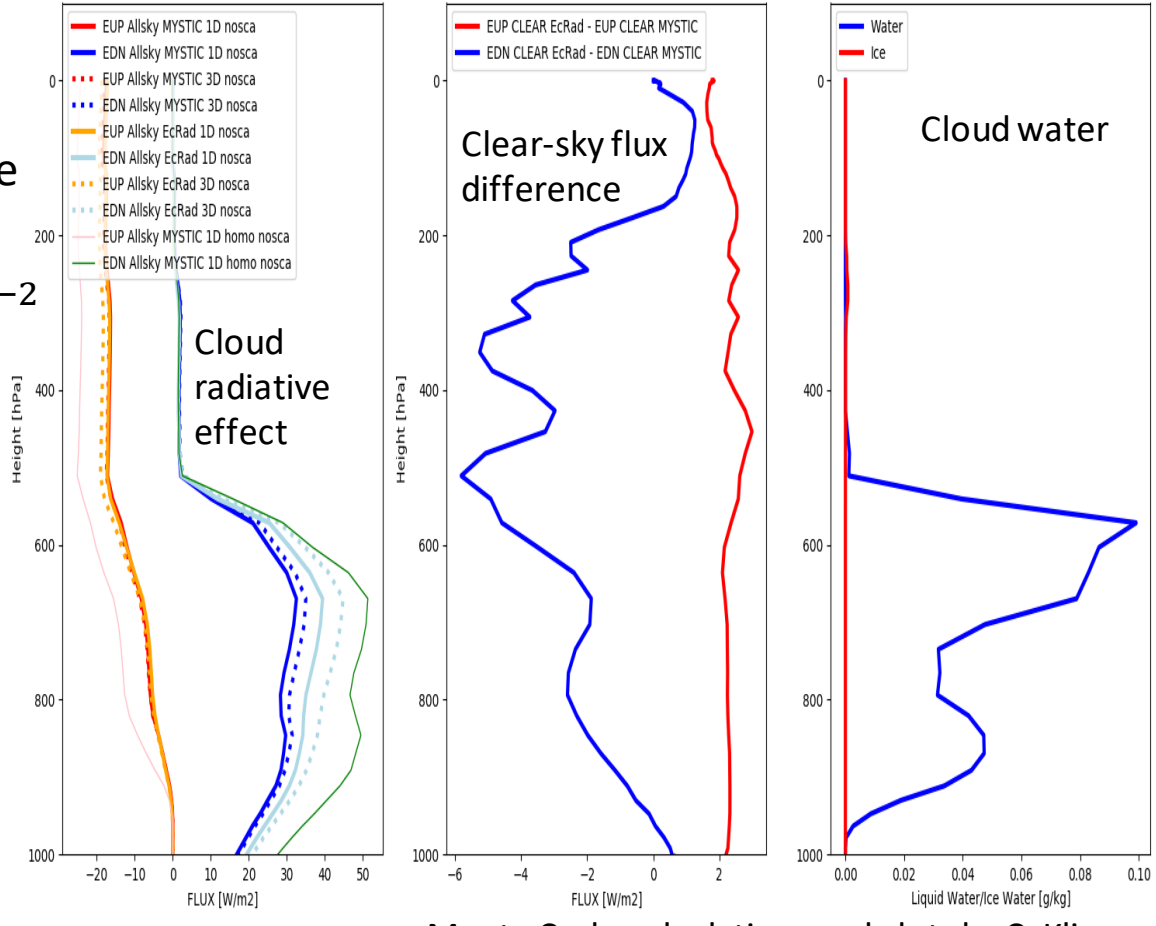
McICA: draw **random clouds in sub-columns** according to overlap + inhomogeneity; **distribute spectral intervals** in 1 sub-column each → **fast, random noise**



Plots adapted from R. Hogan

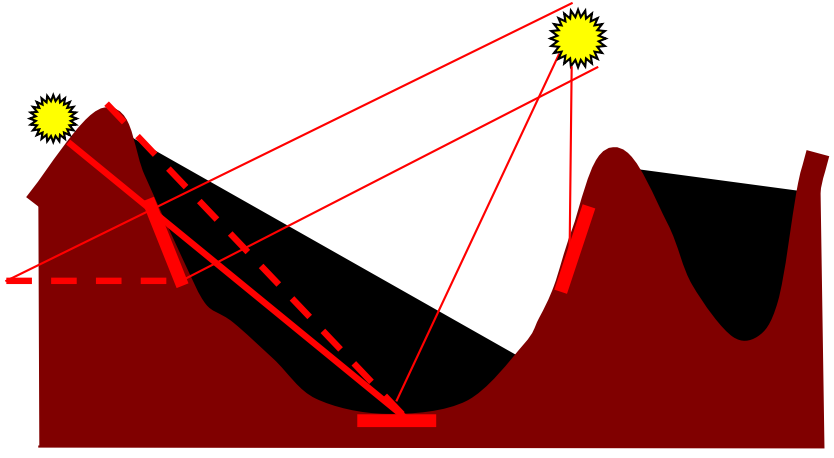
ecRad longwave evaluation (against Monte Carlo scheme)

- **Shortwave:** ecRad compares well with 3D Monte Carlo radiation (Hogan et al., 2019)
- **Longwave:** ecRad and Monte Carlo fluxes **agree well** in simple water or ice clouds, some clear-sky difference due to different gas models
- **Large uncertainty** of up to $30\ \mathrm{Wm}^{-2}$ due to **inhomogeneity**
- **3D effects** of up to $5\ \mathrm{Wm}^{-2}$
- **ecRad captures effects**; somewhat **underestimates inhomogeneity**, **overestimates 3D** effects
- Inhomogeneity between water and ice can be important, not yet represented



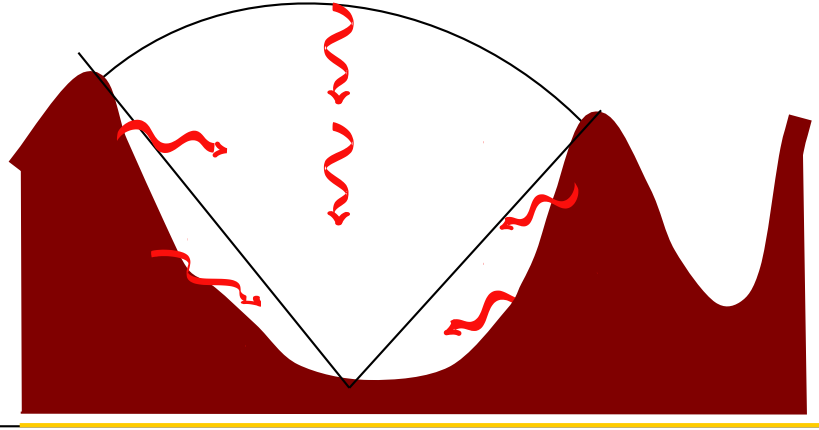
Monte Carlo calculations and plots by C. Klinger

Parameterization of orographic effects on radiation (André Walser, MeteoSwiss)



slope aspect
slope angle
horizon angle
sun elevation angle
sun azimuth angle

Direct shortwave downward radiation

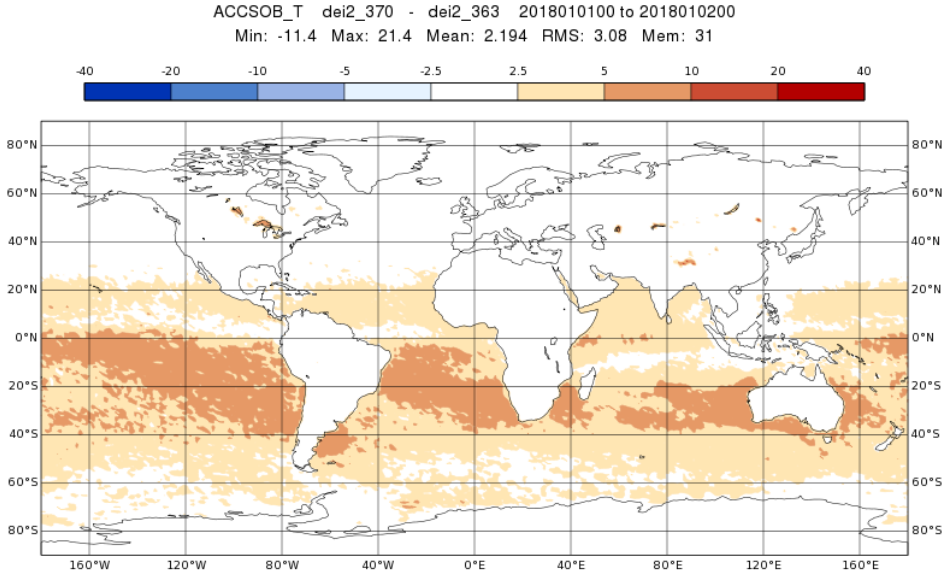


skyview

Downward longwave and diffuse radiation

ocean direct albedo (M. Köhler)

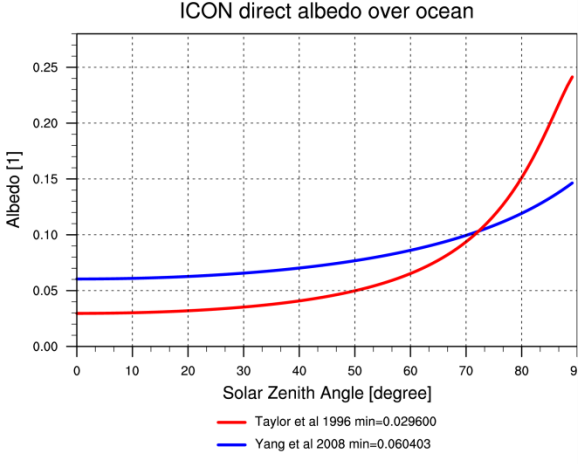
difference IFS-ICON ocean direct albedo



mean difference: 2.194 W/m^2

ICON (40km), January 2018, 31 forecasts of 24h

- ICON: Yang et al. (2008)
- IFS: Taylor et al. (1996)



Try other parametrisations (potentially also for waves / whitecaps)