Priority Project T^2RC^2 :

What can be added to ICON from COSMO?

Tests of cloud-radiation parameters in ICON-D2

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Thanks to:

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[(1)]IMS, [(2)]DWD, [(3)]KIT, [(4)]RMI

ICCARUS, Offenbach, March 2019

Outline

1. What can be added to ICON from COSMO?
2. ICON cloud-radiation scheme – code structure
3. Tuning several ICON cloud-radiation parameters
4. Conclusions

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1. What can be added to ICON from COSMO?
2. ICON cloud-radiation scheme – code structure
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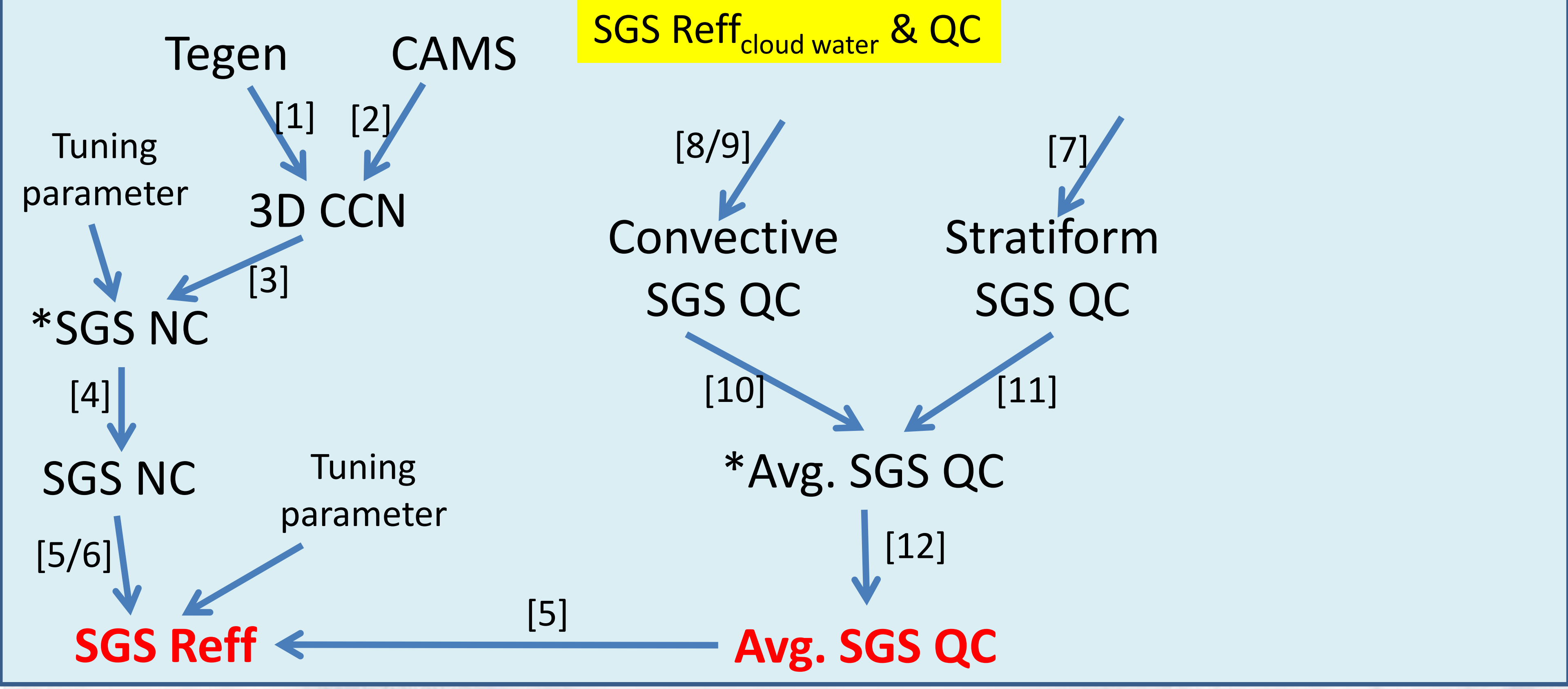
To calculate the optical properties of a cloudy layer we need:

- Subgrid scale QC, grid scale QC,
- GS QR,
- SGS QI, GS QI,
- GS QS,
- GS QG

- Subgrid scale Reff of droplets, grid scale Reff of droplets,
- GS Reff of rain,
- SGS Reff of cloud ice, GS Reff of cloud ice,
- GS Reff of snow,
- GS Reff of graupel

- SGS aspect ratio of cloud ice, GS aspect ratio of cloud ice,
- GS aspect ratio of snow,
- GS aspect ratio of graupel



[1] Tegen 2D AOD field → 3D CCN concentration

[2] CAMS aerosols types concentrations + relative humidity → 3D CCN concentration

[3] Segal-Khain droplets activation from CCN and effective updraft, and their reduction with height

[4] Option for reduction of Nc vs LWC

[5] SGS QC and Nc → Reff=a(Q/N)^b

[6] Reff from SGS Nc through “SAM” parametrization

[7] Stratiform SGS QC= function of saturation mixing ratio. Added radqXfact and qvsatfact_sgs_cl

[8] Convective SGS QC= like [6]: function of saturation mixing ratio. Added radqXfact and qvsatfact_sgs_cl

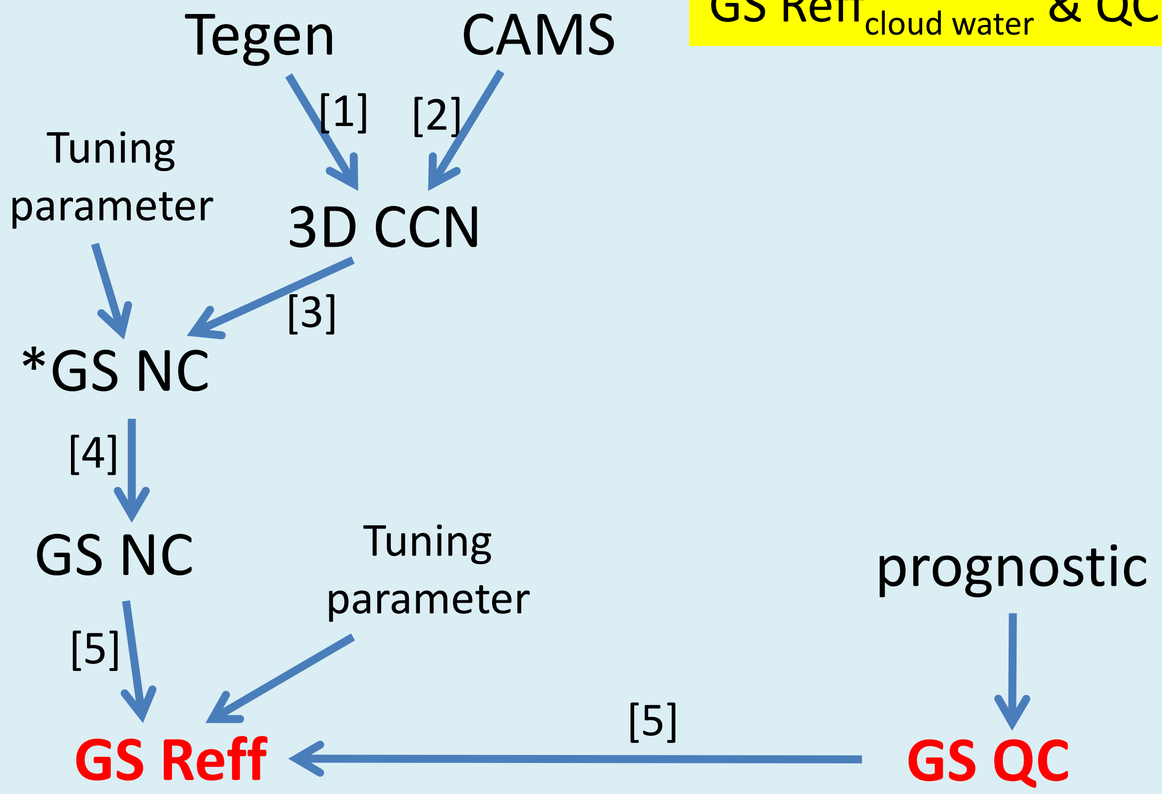
[9] Convective SGS QC from “SAM” parametrization or from shallow convection scheme

[10] Convective SGS CLC from shallow convection scheme (function of clouds depth)

[11] Stratiform SGS CLC from RHg

[12] Reduction of QC if the column integrated value is too high

GS $Reff_{cloud\ water}$ & QC



[1] Tegen 2D AOD field → 3D CCN concentration

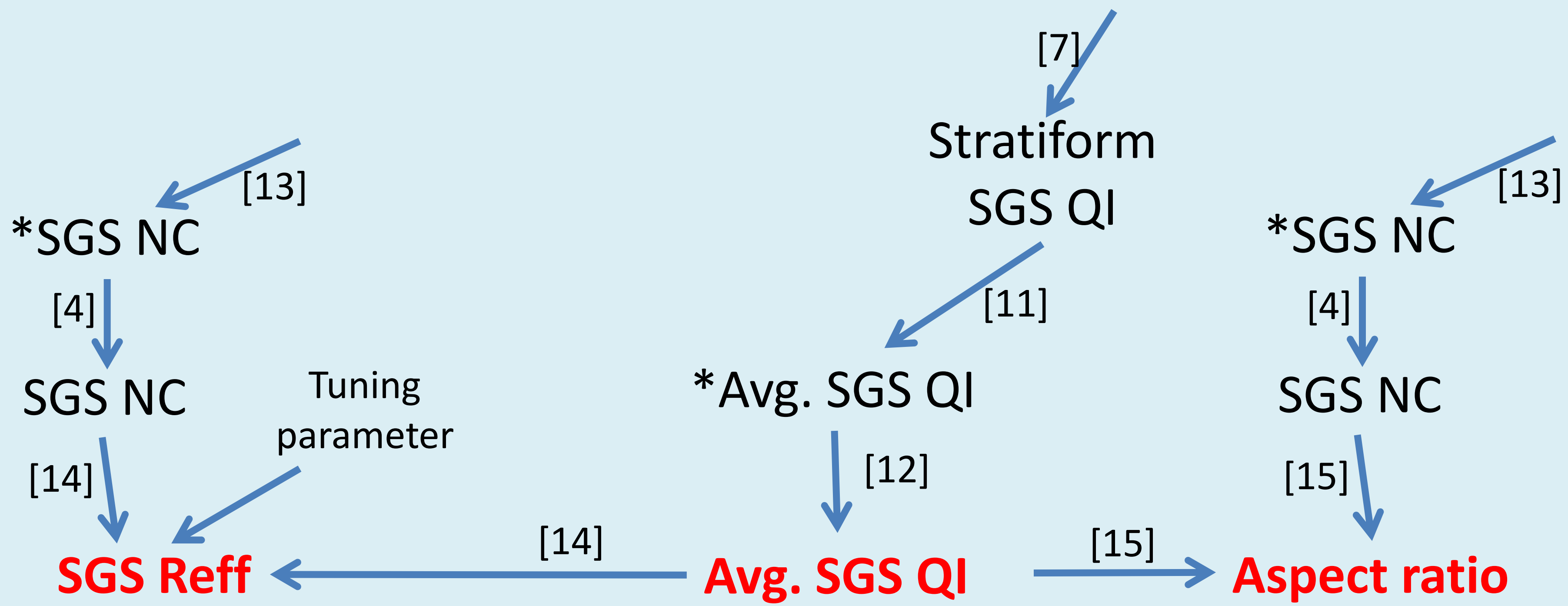
[2] CAMS aerosols types concentrations + relative humidity → 3D CCN concentration

[3] Segal-Khain droplets activation from CCN and effective updraft, and their reduction with height

[4] Option for reduction of Nc vs LWC

[5] SGS QC and Nc → Reff=a(Q/N)^b

SGS Reff$_{cloud\ ice}$ & QI & Aspect ratio$_{cloud\ ice}$



[4] Option for reduction of NC vs QI

[7] Stratiform SGS QI = function of saturation mixing ratio. Added radqXfact and qvsatfact_sgs_cl

[11] Stratiform SGS CLC from RHg

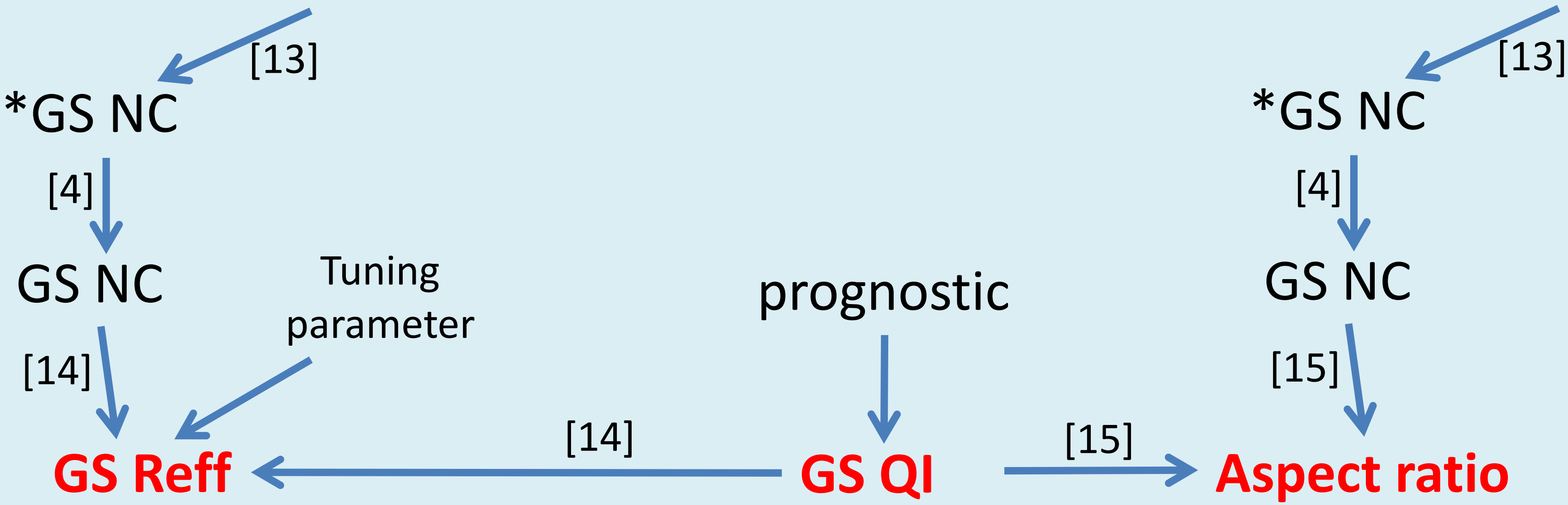
[12] Reduction of QI if the column integrated value is too high

[13] Ice number concentration NC_i=a $\exp[b(T_3\text{-}T)]$

[14] Ice Reff = F(NC_i,QI)

[15] Ice Aspect Ratio = F(NC_i,QI)

GS $Reff_{cloud\ ice}$ & $IWC_{cloud\ ice}$ & Aspect $ratio_{cloud\ ice}$



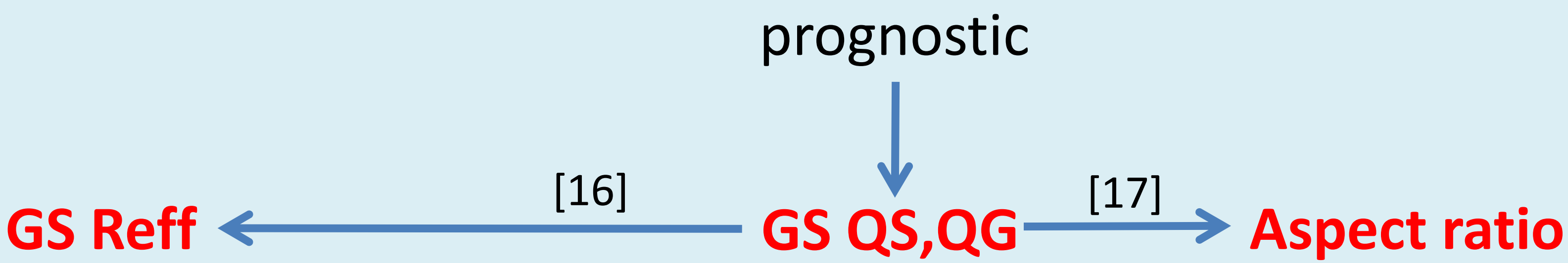
[4] Option for reduction of NC vs QI

[13] Ice number concentration $NC_i = a \exp[b(T_3 - T)]$

[14] Ice Reff = $F(NC_i, QI)$

[15] Ice Aspect Ratio = $F(NC_i, QI)$

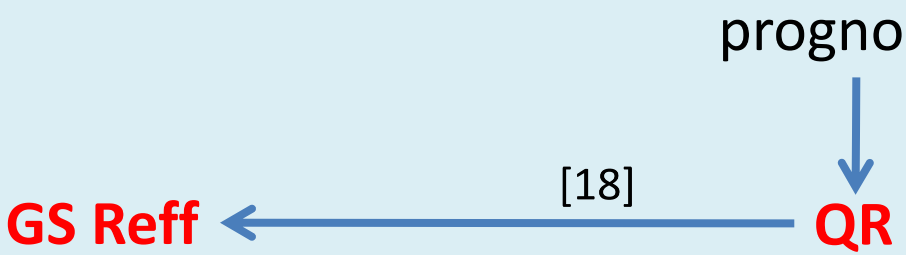
GS $Reff_{snow\&graupel}$ & QS,QG & Aspect $ratio_{snow\&graupel}$



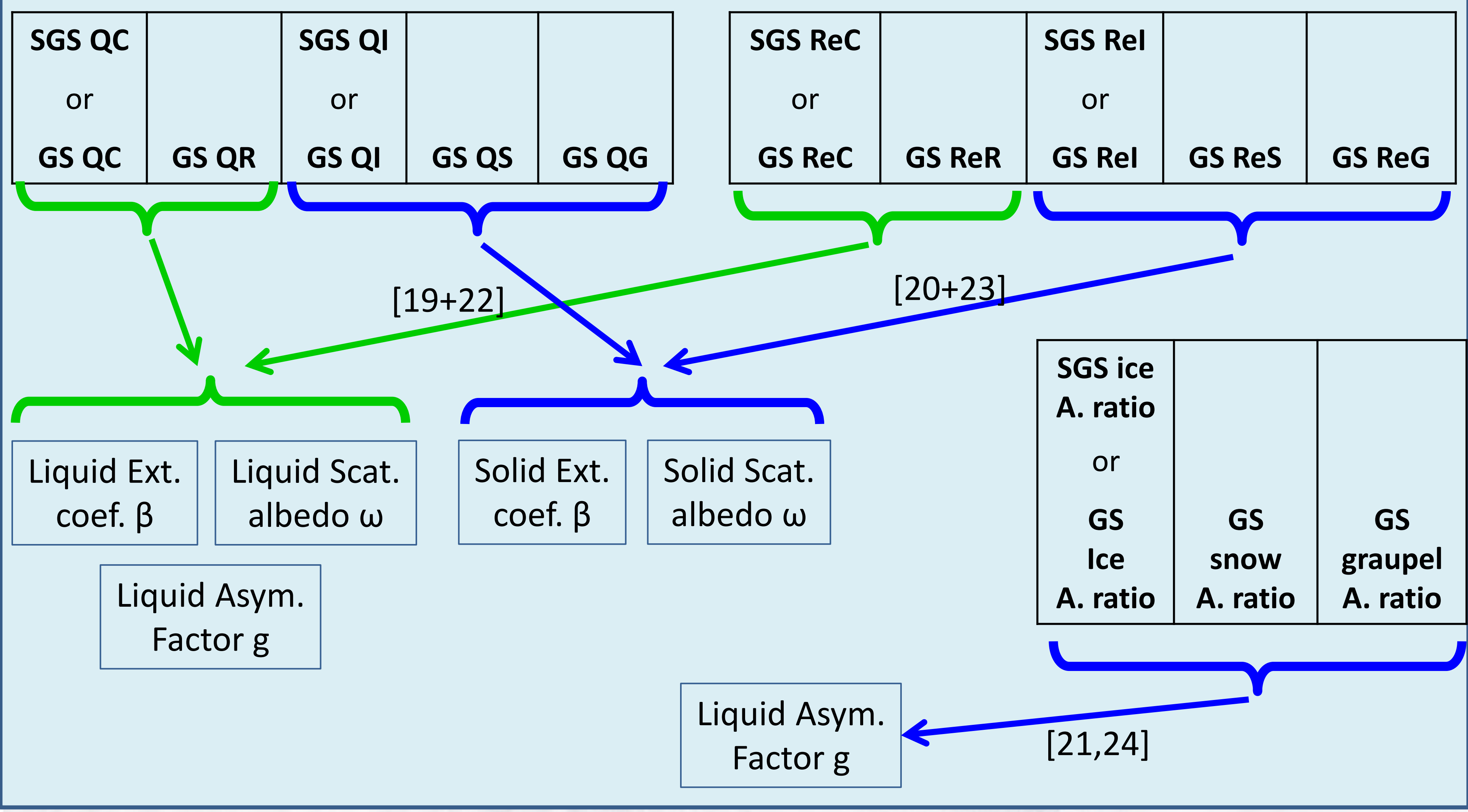
[16] QX → Reff=F(QX,T)

[17] QX → Aspect Ratio=F(QX,T)

GS $Reff_{rain}$ & QR



[18] QR → Reff=a(Q)^b



[19] Fits as function of Reff: Hu and Stamnes (1993)

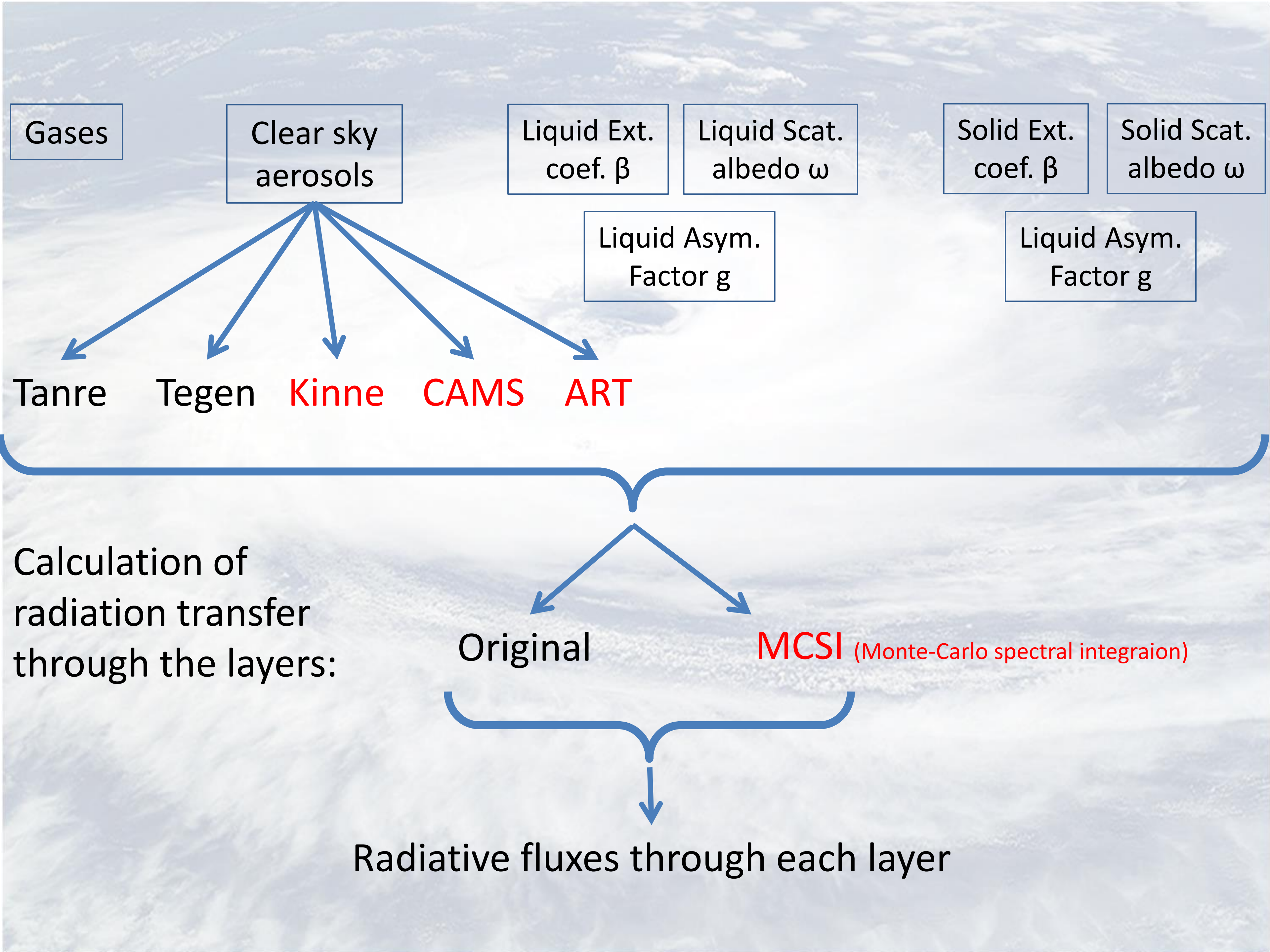
[20] Fits as function of Reff: Fu et al. (1996, 1998)

[21] Fits as function of Asp. ratio: Fu et al. (2007)

[22] Large size approximation for rain: taken not from fits 19, but from geom. approx.

[23] Large size approximation for snow/graupel: taken not from fits 17, but from geom. approx.

[24] Rough/smooth ice&snow surface, fraction of solar forward fraction



Gases
Clear sky aerosols
Liquid Ext. coef. β
Liquid Scat. albedo ω
Solid Ext. coef. β
Solid Scat. albedo ω
Liquid Asym. Factor g
Liquid Asym. Factor g
Tanre
Tegen
Kinne
CAMS
ART
Calculation of radiation transfer through the layers:
Original
MCSI (Monte-Carlo spectral integraion)
Radiative fluxes through each layer

Outline

1. What can be added to ICON from COSMO?
2. ICON cloud-radiation scheme – code structure
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atm_phy_nwp/mo_nh_interface_nwp.f90

SUBROUTINE **nwp_nh_interface**

prepares and postprocesses the fields for and from nwp physics

CALL assimilation_config
CALL nh_update_tracer_phy
CALL satad_v_3D
CALL prog_aerosol_2D
CALL nwp_turbtrans
CALL nwp_surface
CALL nwp_turbdiff
CALL nwp_microphysics
CALL calc_o3_gems
CALL art_reaction_interface
CALL art_washout_interface
CALL organize_lhn
CALL nwp_turbtrans
CALL nwp_convection
CALL cover_koe
CALL nwp_radiation
CALL pre_radiation_nwp
CALL radheat
CALL nwp_gwdrag
CALL apply_ls_forcing
CALL art_diagnostics_interface

atm_phy_schemes/mo_cover_koe.f90

SUBROUTINE cover_koe

```
! Select desired cloud cover framework
SELECT CASE( icldscheme )

    ! no clouds
    CASE( 0 )
        qc_tot(jl,jk) = 0.0_wp
        qi_tot(jl,jk) = 0.0_wp
        cc_tot(jl,jk) = 0.0_wp

    ! diagnostic cloud cover
    CASE( 1 )
      ! stratiform cloud
      ! liquid cloud: quadratic increase of cloud cover from 0 to 1 between RH = (100 -
      2.5*asyfac*tune_box_liq)% and (100 + tune_box_liq)%
      ! the additional asymmetry factor asyfac is 1.25 in subsaturated air at temperatures above freezing
      and smoothly decreases to 1 if clouds are present and/or cold temperatures. Diagnosed cloud water
      is proportional to clcov**2
      !ice cloud: assumed box distribution, width 0.1 qisat, saturation above qv (qv is microphysical
      threshold for ice as seen by grid scale microphysics)
      ! convective cloud
      ! Assume 2% cloud cover in non-detraining updraft region
      ! additional source term for convective clouds depending on detrained cloud water (qc_tend) and RH
    ! prognostic total water variance (missing!)
    CASE( 2 )
        qc_tot(jl,jk) = 0.0_wp
        qi_tot(jl,jk) = 0.0_wp
        cc_tot(jl,jk) = 0.0_wp

    ! clouds as in COSMO
    CASE( 3 )
        CALL cover_cosmo

    ! cloud cover as in turbulence
    CASE( 4 )
        CALL cloud_diag

    ! grid-scale cloud cover [1 or 0]
    CASE( 5 )
        IF ( qc(jl,jk) + qi(jl,jk) > zcldlim ) THEN
            cc_tot(jl,jk) = 1.0_wp
        ELSE
            cc_tot(jl,jk) = 0.0_wp
        ENDIF
        qc_tot(jl,jk) = qc(jl,jk)
        qi_tot(jl,jk) = qi(jl,jk)
```

```
!> Cloud water distribution: cloud cover, cloud water, cloud ice
!  inwp_cldcover =
!  (0) no clouds
!  (1) diagnostic cloud cover
!  (2) prognostic total water variance (not yet started)
!  (3) clouds as in COSMO
!  (4) clouds as in turbulence
!  (5) grid-scale cloud cover [1 or 0]
```

Calculation of CLC and QC,QI

atm_phy_schemes/mo_cover_cosmo.f90

SUBROUTINE cover_cosmo

```
!------------------------------------------------------------------------------
! Section 3:  Set cloudiness and humidity on input for fesft;
!             Store cloud cover on corresponding global arrays
!------------------------------------------------------------------------------
    !------------------------------------------------------------------------------
    ! Section 3.0: Calculate convective cloud cover by a simple empirical Relation
    !------------------------------------------------------------------------------
    clc_con(i,k) = 0.7_ireals/10000.0_ireals * ( pgeo(i,kctop(i)) - pgeo(i,kcbot(i)) ) / grav

    !------------------------------------------------------------------------------
    ! Section 3.1: Calculate water vapour saturation mixing ratios of over water and over ice
    !------------------------------------------------------------------------------
    !------------------------------------------------------------------------------
    ! Section 3.2: Calculate stratiform cloud cover (non-convective)
    !------------------------------------------------------------------------------

    IF     ( icldm_rad == 0 ) THEN
        ! a) No interpretation of clouds at all for radiative calculations
    ELSEIF ( icldm_rad == 1 ) THEN
        ! b) Only grid-sale water clouds are passed to the radiation routine
        zclwc(i,k) = qc(i,k,nzx)
        zciwc(i,k) = qi(i,k,nnow)
        zclc(i,k)= 0 or 1
        clc_sgs(i,k) = zclc(i,k)
    ELSEIF ( icldm_rad == 3 ) THEN
        ! c) Cloud cover and water content from statistical diagnosis
        CALL cloud_diag
    ELSEIF ( icldm_rad == 4 .OR. icldm_rad == 3 ) THEN
        ! a) Standard diagnosis
        clc_sgs(i,k) = zcs        *the triangle area like with Uli
        zsex     = zsw(i,k) * (1.0_ireals - zf_ice) + zse(i,k)*zf_ice
        zclws  = 0.005_ireals*zsex
        zclwcs = zclws*(1.0_ireals-zf_ice)
        zclics = zclws*zf_ice

        ! Convective cloud water / ice content
        zclwk  = MAX( 2.0_ireals*zclws, 0.0002_ireals )
        zclwck = zclwk*(1.0_ireals-zf_ice)
        zclick = zclwk*zf_ice
```

sgs clc, qc and qi are obtained like in Uli's slide 4. qvsat_fact_sgs_cl, radqc_fact and radqi_fact are hidden here !!!

atm_phy_nwp/mo_nh_interface_nwp.f90

SUBROUTINE **nwp_nh_interface**

prepares and postprocesses the fields for and from nwp physics

CALL assimilation_config
CALL nh_update_tracer_phy
CALL satad_v_3D
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CALL nwp_turbtrans
CALL nwp_surface
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CALL nwp_microphysics
CALL calc_o3_gems
CALL art_reaction_interface
CALL art_washout_interface
CALL organize_lhn
CALL nwp_turbtrans
CALL nwp_convection
CALL cover_koe
CALL nwp_radiation ←
CALL pre_radiation_nwp
CALL radheat
CALL nwp_gwdrag
CALL apply_ls_forcing
CALL art_diagnostics_interface

atm_phy_nwp/mo_nwp_rad_interface.f90

This module is the interface between nwp_nh_interface to the radiation schemes (RRTM or Ritter-Geleyn).
@author Thorsten Reinhardt, AGeoBw, Offenbach

```
SUBROUTINE nwp_radiation

   CALL pre_radiation_nwp_steps

   CALL sfc_albedo

   SELECT CASE (atm_phy_nwp_config(jg)%inwp_radiation)
     CASE (1, 3) ! RRTM / PSRAD
       irad = atm_phy_nwp_config(jg)%inwp_radiation
       CALL nwp_ozon_aerosol
       IF ( .NOT. lredgrid ) THEN
         CALL nwp_rrtm_radiation
       ELSE
         CALL nwp_rrtm_radiation_reduced
       ENDIF
     CASE (2) ! Ritter-Geleyn
       IF (.NOT. lredgrid) THEN
         CALL nwp_rg_radiation
       ELSE
         CALL nwp_rg_radiation_reduced
       ENDIF
   END SELECT ! inwp_radiation
```

RRTM scheme

RG scheme

atm_phy_nwp/mo_nwp_rrtm_interface.f90

This module is the interface between nwp_nh_interface to the radiation schemes (RRTM or Ritter-Geleyn).
@author Thorsten Reinhardt, AGeoBw, Offenbach

```
SUBROUTINE nwp_ozon_aerosol

SUBROUTINE nwp_rrtm_radiation

   CALL radiation_nwp

SUBROUTINE nwp_rrtm_radiation_reduced

   CALL upscale_rad_input
   CALL radiation_nwp
   CALL downscale_rad_output
```

Parallel to fesft!

atm_phy_nwp/mo_nwp_rg_interface.f90

This module contains various interfaces to the Ritter-Geleyn radiation scheme.
@author Thorsten Reinhardt, AGeoBw, Offenbach

```
SUBROUTINE nwp_rg_radiation

   CALL nwp_ozon_aerosol

   CALL fesft

SUBROUTINE nwp_rg_radiation_reduced

   CALL nwp_ozon_aerosol

   CALL upscale_rad_input_rg

   CALL fesft

   CALL downscale_rad_output_rg
```

atm_phy_schemes/mo_radiation_rg.f90

Ritter-Geleyn radiation parameterization from
GME (provided by Bodo Ritter, DWD, Offenbach)
@author Thorsten Reinhardt, AGeoBw, Offenbach
(Implementation into ICON)

SUBROUTINE **fesft**

SUBROUTINE opt_th
SUBROUTINE inv_th
SUBROUTINE opt_so
SUBROUTINE inv_so
SUBROUTINE coe_th
SUBROUTINE coe_so

```
! This routine organizes the radiative transfer calculations by
! calling a set of dedicated routines for the calculation of
! basic optical properties (opt_th/opt_so), the derivation of
! layer coefficients (coe_th/coe_so) for an implicit delta-two-
! stream scheme (cf.Ritter and Geleyn, 1992) and the inversion
! (inv_th/inv_so) of the corresponding system matrix. These
! operations are performed seperately for thermal and solar parts
! of the spectrum and are embedded in loops over the various
! spectral intervals. Within each interval, a data-controlled
! decision is taken, whether the so-called ESFT or FESFT approach
! is used for the handling of gaseous absorption (cf. Ritter and
! Geleyn, 1992).
! Controlled by the logical input variable LCRF, the calculation
! of radiative fluxes in cloud-free conditions can be done in
! addition to the results for the given atmospheric cloud structure.
! (not implemented yet)
! Before the actual flux calculation starts, some preliminary steps
! provide utility arrays which are applicable to all spectral inter-
! vals (e.g. cloud geometry factors, integrated layer water content,
! etc.)
```

atm_phy_nwp/mo_nwp_rad_interface.f90

This module is the interface between nwp_nh_interface to the radiation schemes (RRTM or Ritter-Geleyn).
@author Thorsten Reinhardt, AGeoBw, Offenbach

```
SUBROUTINE nwp_radiation

    CALL pre_radiation_nwp_steps

    CALL sfc_albedo

    SELECT CASE (atm_phy_nwp_config(jg)%inwp_radiation)
      CASE (1, 3) ! RRTM / PSRAD
        irad = atm_phy_nwp_config(jg)%inwp_radiation
        CALL nwp_ozon_aerosol
        IF ( .NOT. lredgrid ) THEN
          CALL nwp_rrtm_radiation
        ELSE
          CALL nwp_rrtm_radiation_reduced
        ENDIF
      CASE (2) ! Ritter-Geleyn
        IF (.NOT. lredgrid) THEN
          CALL nwp_rg_radiation
        ELSE
          CALL nwp_rg_radiation_reduced
        ENDIF
    END SELECT ! inwp_radiation
```

RRTM scheme

atm_phy_nwp/mo_nwp_rrtm_interface.f90

This module is the interface between nwp_nh_interface to the radiation schemes (RRTM or Ritter-Geleyn).
@author Thorsten Reinhardt, AGeoBw, Offenbach

```
SUBROUTINE nwp_ozon_aerosol

SUBROUTINE nwp_rrtm_radiation

    CALL radiation_nwp

SUBROUTINE nwp_rrtm_radiation_reduced

    CALL upscale_rad_input
    CALL radiation_nwp
    CALL downscale_rad_output
```

→ *Parallel to fesft!*

RG scheme

atm_phy_nwp/mo_nwp_rg_interface.f90

This module contains various interfaces to the Ritter-Geleyn radiation scheme.
@author Thorsten Reinhardt, AGeoBw, Offenbach

```
SUBROUTINE nwp_rg_radiation

    CALL nwp_ozon_aerosol

    CALL fesft

SUBROUTINE nwp_rg_radiation_reduced

    CALL nwp_ozon_aerosol

    CALL upscale_rad_input_rg

    CALL fesft

    CALL downscale_rad_output_rg
```

configure_model/mo_radiation_config.f90

```
! --- Cloud optical properties
  INTEGER :: irad_calc_opt          !< Method for calculating optical properties
                                    ! 0 = reff [1], fits [1]
                                    ! 1 = reff [2], fits [3], for 1mom microphysics
                                    ! 2 = reff [2], fits [3], for 1mom microphysics, with qr, qs, qg
                                    ! 3 = reff [2], fits [3], for 2mom microphysics
                                    ! 4 = reff [2], fits [3], for 2mom microphysics, with qr, qs, qg
                                    ! 5 = reff [2], fits [1], for 1mom microphysics
                                    ! 6 = reff [2], fits [1], for 2mom microphysics, with qr, qs, qg
                                    !      (NOT WORKING!)
                                    ! [1]: Roeckner et al., 2003 (MPI report 349)
                                    ! [2]: Fu, 1996; Fu et al., 1998; Fu, 2007
                                    ! [3]: from Muskatel, Blahak (2017)
  LOGICAL :: irad_use_largesizeapprox !< if irad_calc_opt = {1,4,6}, our original new fits
                                    ! for all optical properties of solid species are used without
                                    ! clipping. If .true., only for the extinction the large-size
                                    ! approximation is applied starting from Reff = 150 um.
```

```
IF (irad_calc_opt == 0) THEN ! old version
    CALL newcld_optics
ELSE ! new version
    ! init structure for calculation of reff and optical properties
    CALL opt_cloud%init
    CALL opt_ice%init
    SELECT CASE(irad_calc_opt)
      CASE (2,4) ! include also rain, snow and graupel
        CALL opt_rain%init
        CALL opt_snow%init
        CALL opt_graupel%init
    END SELECT ! irad_calc_opt
    ! calculate reff and optical properties
    CALL cloud_opt
    ! calculate water path of hydrometeor species considered
    ! calculate input for rrtm (ext, ssa, asy)
    CALL newcld_optics
END IF ! irad_calc_opt
```

changed

atm_phy_schemes/mo_radiation.f90

This module contains routines that provide the interface between ECHAM and the radiation code. Mostly it organizes and calculates the information necessary to call the radiative transfer solvers. @author Bjorn Stevens, MPI-M, Hamburg (2009-09-19)

```
SUBROUTINE pre_radiation_nwp_steps
SUBROUTINE pre_radiation_nwp
SUBROUTINE radiation
    CALL rrtm_interface
SUBROUTINE radiation_nwp
    CALL rrtm_interface
SUBROUTINE rrtm_interface
    SELECT CASE (irad_aero)
    CASE (9)
      CALL art_rad_aero_interface
    CASE (13)
      CALL set_bc_aeropt_kinne
    …
    IF (irad == 1) THEN
      CALL newcld_optics
    ELSE
      CALL psrad_cloud_optics
    ENDIF
    IF (irad == 1) THEN
      CALL lrtm
    ELSE
      CALL psrad_lrtm
    ENDIF
    IF (irad == 1) THEN
      CALL srtm_srtm_224gp
    ELSE
      CALL psrad_srtm
    ENDIF
SUBROUTINE radheat
    CALL calculate_psrad_radiation_forcing
```

@brief Organizes the calls to the ratiation solver
@remarks This routine organises the input/output for the radiation computation. The state of radiatively active constituents is set as the input. Output are flux transmissivities (ratio solar flux/solar input) and thermal fluxes at all the half levels of the grid. This output will be used in radheat at all time steps until the next full radiation time step.

@brief Organizes the calls to the radiation solver
@remarks This routine organises the input/output for the radiation computation. The state of radiatively active constituents is set as the input. Output are flux transmissivities and emissivities at all the half levels of the grid (respectively ratio solar flux/solar input and ratio thermal flux/local black-body flux). This output will be used in radheat at all time steps until the next full radiation time step.

Compute shortwave and longwave heating rates
The radheat subroutine computes the radiative heating rates resulting from
the divergence of the vertical profiles of longwave and shortwave net fluxes.
- Shortwave net flux profiles are computed from:
- the vertical profiles of net transmissivity
- the solar incoming flux at TOA
- Longwave net flux profiles are given as input
- Specific heat depends on the moisture in the air
@author Marco Giorgetta, Max Planck Institute for Meteorology

atm_phy_schemes/mo_cloud_opt.f90

SUBROUTINE cloud_opt ! Subroutine for set particle types, call routines for calculation of cloud optical properties

```
 SELECT CASE(irad_calc_opt)
   CASE(1,2,5)
! cloud droplets
     ALLOCATE(qnc_loc(istart:ipend,kstart:ke))
     qnc_loc = cloud_num_rad
     do_qnc_profile = .true.
     CALL opt_cloud%calc_1mom_liquid
! cloud ice
     CALL opt_ice%calc_1mom_frozen
! sub grid scale effective radii
!!     CALL opt_ice%calc_1mom_frozen_sub
  END SELECT

  SELECT CASE(irad_calc_opt)
   CASE(2)
 ! rain
     CALL opt_rain%calc_1mom_liquid
 ! snow
    ! diagnose the N0-parameter of snow
     CALL calc_n0_snow
     CALL opt_snow%calc_1mom_frozen
! graupel
     IF (atm_phy_nwp_config(jg)%inwp_gscp /= 1) THEN
      CALL opt_graupel%calc_1mom_frozen
     END IF ! inwp_gscp /= 1
  END SELECT
```

```
 SELECT CASE(irad_calc_opt)
   CASE(1,2,3,4)
    ! Calculate optical properties
     CALL opt_cloud%calc_opt_liquid
     CALL opt_cloud%calc_opt_liquid
     CALL opt_ice%calc_opt_frozen
     CALL opt_ice%calc_opt_frozen
  END SELECT
  SELECT CASE(irad_calc_opt)
   CASE(2,4)
     CALL opt_rain%calc_opt_liquid
     CALL opt_rain%calc_opt_liquid
     CALL opt_snow%calc_opt_frozen
     CALL opt_snow%calc_opt_frozen
     CALL opt_graupel%calc_opt_frozen
     CALL opt_graupel%calc_opt_frozen
END SELECT
```

mo_cloud_opt_calc.f90

! SUBROUTINE init	! Subroutine for allocation and setting of initial values
! SUBROUTINE destruct	! Subroutine for deallocation
! SUBROUTINE init_2mom_frozen_sub	! Subroutine for calculation of prefactors for effective radii
! SUBROUTINE init_1mom_frozen_mono	! Subroutine for calculation of prefactors for effective radii
! SUBROUTINE init_1mom_rain	! Subroutine for calculation of prefactors for effective radii
! SUBROUTINE init_2mom_frozen	! Subroutine for calculation of prefactors for effective radii
! SUBROUTINE init_2mom_liquid	! Subroutine for calculation of prefactors for effective radii
! SUBROUTINE init_1mom_frozen_poly	! Subroutine for calculation of prefactors for effective radii
! SUBROUTINE **calc_1mom_frozen**	! Subroutine for calculation of effective radii
! SUBROUTINE **calc_1mom_liquid**	! Subroutine for diagnosis of effective radii for gridscale clouds
! SUBROUTINE calc_2mom_frozen	! Subroutine for calculation of effective radii
! SUBROUTINE calc_2mom_liquid	! Subroutine for calculation of effective radii
! SUBROUTINE **calc_1mom_frozen_sub**	! Subroutine for diagnosis of the subgrid scale ice effective radii
! SUBROUTINE calc_2mom_frozen_sub	! Subroutine for diagnosis of the subgrid scale ice effective radii
! SUBROUTINE **calc_opt_frozen**	! Subroutine for calculation of cloud optical properties
! SUBROUTINE **calc_opt_liquid**	! Subroutine for calculation of cloud optical properties

calc_opt_liquid

! Subroutine for calculation of cloud optical properties
! Parameterization based on Hu and Stamnes (1993) - spectrally remapped by Elias Zubler
! NEW fit coefficients and slightly modified code! (Blahak, 2016)
! Parameterization according to Hu & Stamnes (1993), which is based in parts
! on Ackerman and Stephens (1987), Tsay (1989)

calc_opt_frozen

! Subroutine for calculation of cloud optical properties
! Using new fits from Harel Muskatel (IMS) and Ulrich Blahak (DWD) for
! the whole size range of frozen hydrometeors.
! Parameterization based on Fu, 1996; Fu et al., 1998; Fu ,2007

calc_1mom_liquid

Subroutine for diagnosis of effective radii for gridscale clouds

calc_1mom_frozen

Subroutine for calculation of effective radii
! Generic routine for all ice (frozen) species

calc_1mom_frozen_sub

! Subroutine for diagnosis of the subgrid scale ice effective radii
! Radii for the following definitions are calculated:
! cloud ice, : reff after definition of Fu et al. (1998)
! (for both hexagonal plates and hexagonal columns, randomly oriented)

Outline

1. What can be added to ICON from COSMO?
2. ICON cloud-radiation scheme – code structure
3. Tuning several ICON cloud-radiation parameters
4. Conclusions

Overview

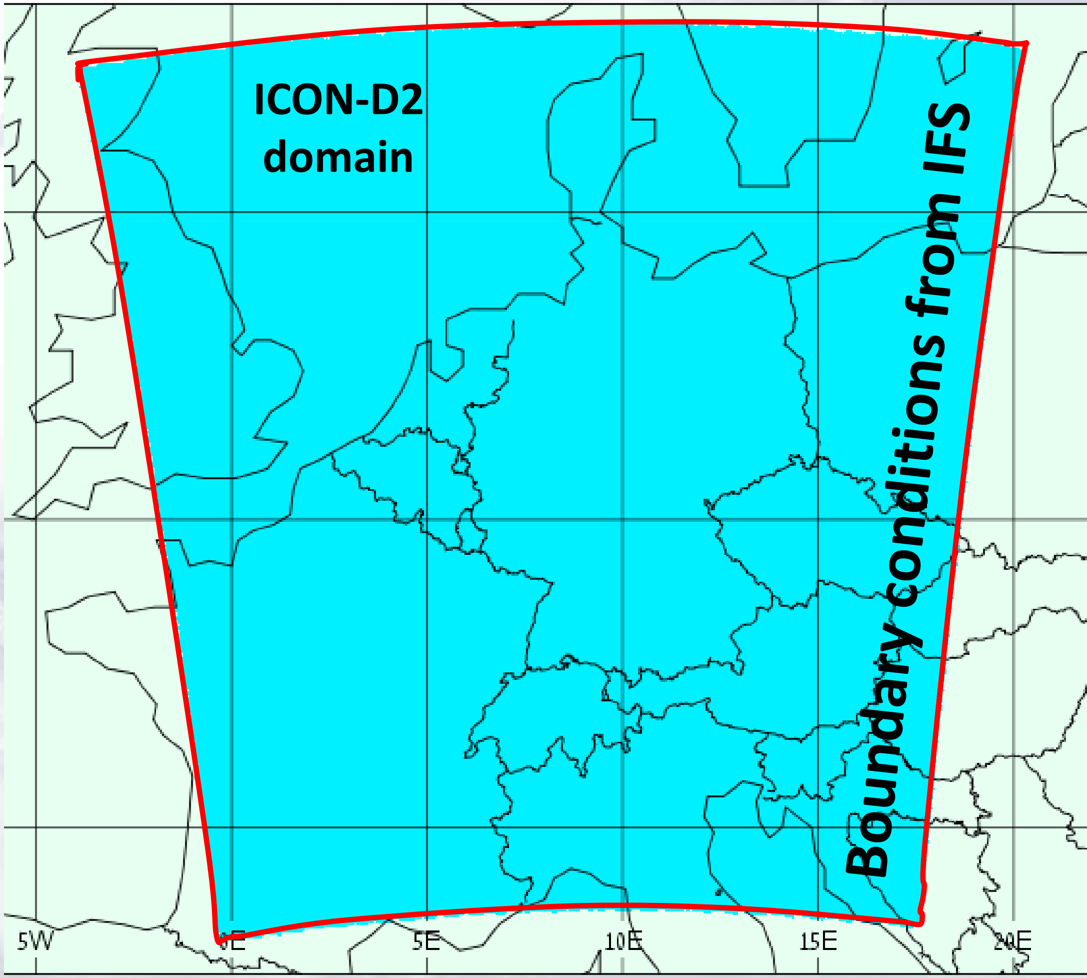
Priority Project "Testing and Tuning of Revised Cloud Radiation Coupling" (T^2RC^2) aims at the development of the new cloud-radiation coupling scheme in COSMO and its implementation into ICON. The new scheme includes revised sub-grid scale clouds effect on radiation, detailed optical properties for liquid and frozen particles of different sizes, more accurate representation of aerosol effects on cloud microphysics, etc. From algorithmical point of view, the new scheme contains many cloud-radiation dependencies which contribution is described by about thirty parameters. Besides, different options are activated using ten logical switches. This makes the tuning of the scheme a difficult problem. Last year, the parameters which have particularly high influence on the radiative fluxes in the model underwent massive tuning via comparison of COSMO-DE forecasts against global radiation observations.

Part of the new cloud-radiation coupling scheme is already implemented in ICON. Here, the influence of the relevant parameters on global radiation forecasts of ICON-DE is being tested.

We present preliminary verification results of ICON-DE tests for several month during 2016.

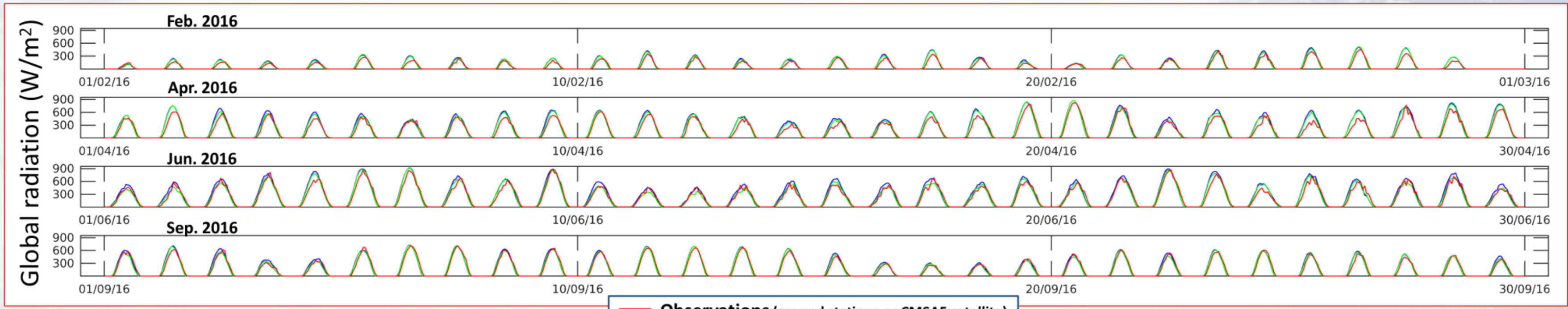
Abstract

- *We have verified 10 versions of ICON-DE ~2.8km resolution, driven by IFS.*
- *These versions differ by cloud-radiation parametrizations.*
- *Global radiation forecasts were verified against 27 ground stations over Germany and against CMSAF satellite.*
- *Verification periods: February, April, June and September 2016.*
- *The model global radiation was compared to observations only in cases of adequate forecast of cloudiness.*

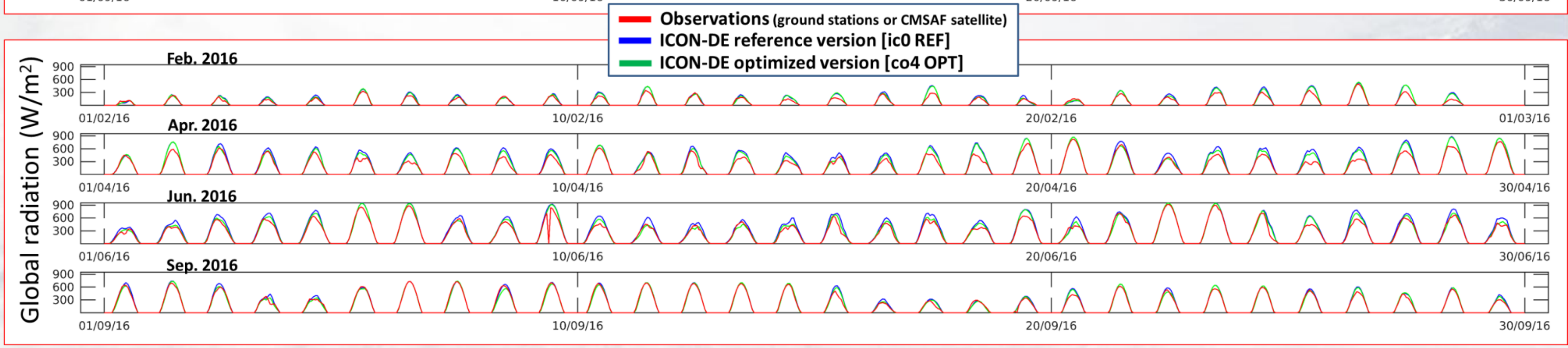


Time series for verification

Global radiation ***averaged*** over 27 ground stations over Germany



Global radiation from CMSAF satellite, ***averaged*** over Offenbach, Lindenberg and Munich 100X100 km² areas



ICON cloud-radiation parameters

inwp_cldcover	irad_calc_opt	lrad_use_ largesizeapprox	radqc_fact, radqi_fact	qvsat_fact_ sgscl_rad
Cloud cover diagnostics [1] ICON scheme (by M. Köhler) [3] COSMO new scheme (by U. Blahak)	**Method for calculating cloud optical properties** [0] Reff from (a), fits from (a) [1] Reff from (b), fits from (c) [2] Reff from (b), fits from (c), with qr,qs,qg [5] Reff from (b), fits from (a) (a) Roeckner et al., 2003 (MPI report 349) (b) Fu, 1996; Fu et al., 1998; Fu, 2007 (c) Muskatel and Blahak (2017)	**Application of large size approximation** (instead of fits) for species larger than 150um [True/False]	**Sub-grid variability factor for liquid and ice water contents** [0.4-0.9]. Tuning parameter	**Scaling factor for sub-grid scale liquid water content** [0.005-0.02]. Tuning parameter

Verified ICON versions

Version	inwp_cldcover	irad_calc_opt	lrad_use_ largesizeapprox
REF ic0	1	0	F
ic1	1	1	F
ic2	1	5	F
ic3	1	2	F
ic4	1	2	T
co0	3	0	F
co1	3	1	F
co2	3	5	F
co3	3	2	F
co4	3	2	T

Calibrating parameters of version co4

Version	radqc_fact, radqi_fact	qvsat_fact_ sgscl_rad
co4	0.5	0.01
co4_a	0.4	0.01
co4_b	0.9	0.01
co4_c	0.5	0.005
co4_d	0.5	0.02
co4_e	0.9	0.02

Calibration result

co4 OPT vs. ground stations	0.52	0.014
co4 OPT vs. CMSAF satellite	0.79	0.009

How to calibrate?

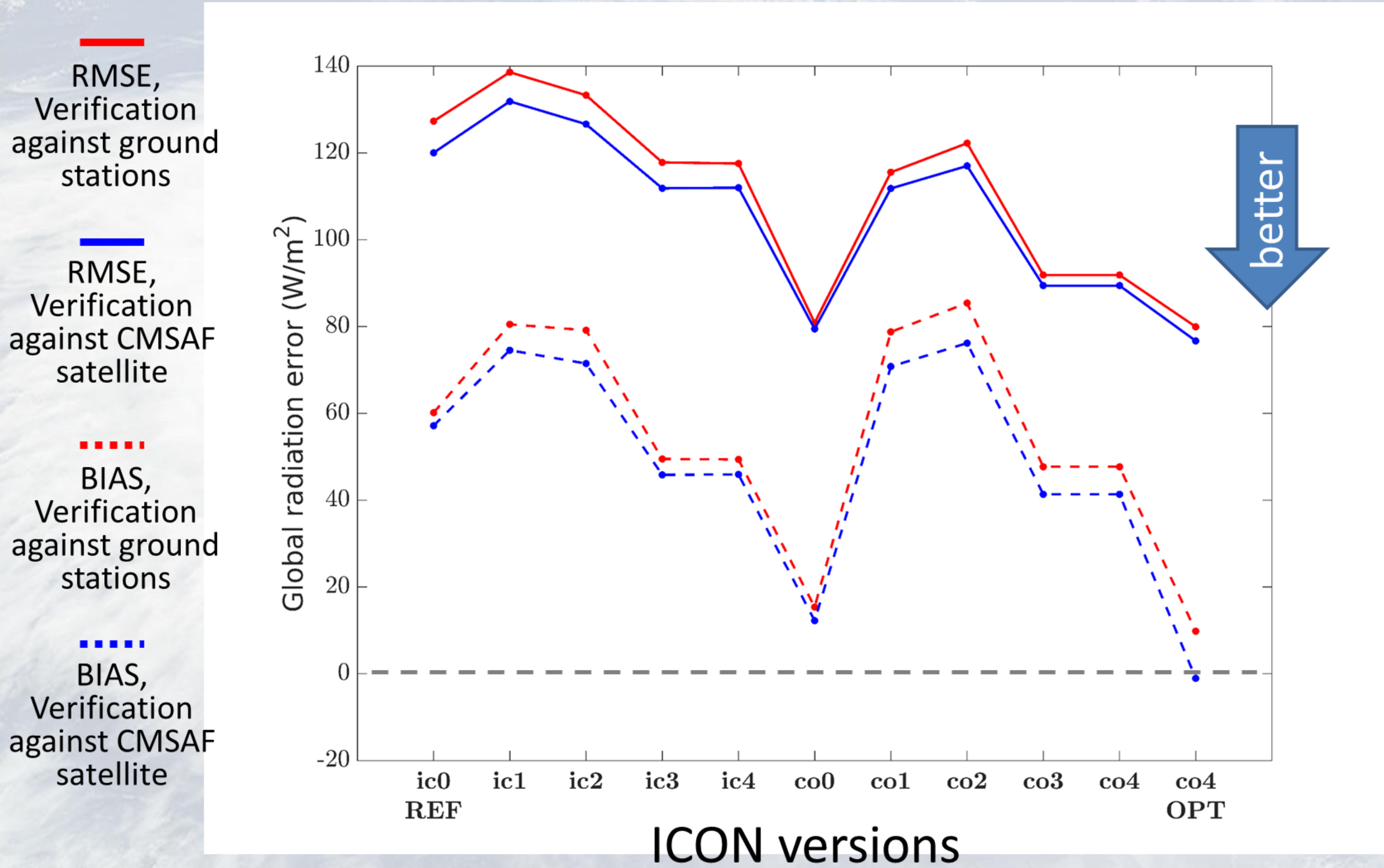
Meta-Model

- ***For co4 version, 2 continuous parameters were calibrated.***
- ***First, several parameters combinations were chosen according to specific design (Voudouri et al. 2017). For each combination, ICON-DE runs were performed.***
- ***For every hour at every grid point, the forecast of global radiation is then interpolated in parameters space using 2nd order polynomial.***
- ***These interpolations yield a "guess" for the global radiation for any chosen parameters combination (Meta-Model).***

Optimization

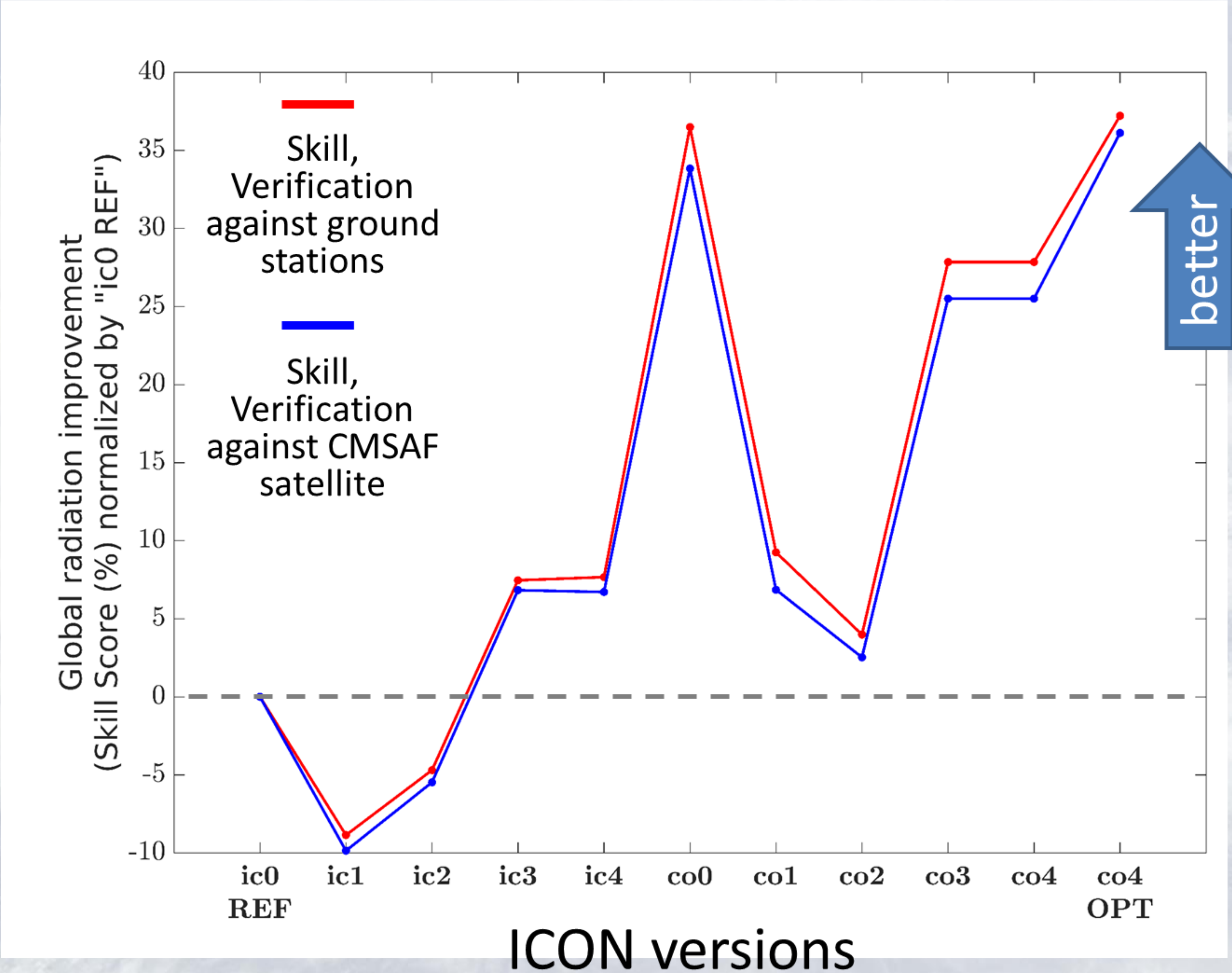
- ***The parameters space is then sampled by large number of parameter combinations. For each combination the Meta-Model is verified against hourly observations data.***
- ***The seek of the optimal parameters combination is performed by convergence algorithm (Khain et al. 2017).***
- ***Finally the parameters combination which yields the optimal Meta-Model guess is defined.***

Results



RMSE, Verification against ground stations
RMSE, Verification against CMSAF satellite
BIAS, Verification against ground stations
BIAS, Verification against CMSAF satellite
Global radiation error (W/m2)
140
120
100
80
60
40
20
0
-20
better
ic0 REF
ic1
ic2
ic3
ic4
co0
co1
co2
co3
co4
co4 OPT
ICON versions

Results



Global radiation improvement
(Skill Score (%) normalized by "ic0 REF")
40
35
30
25
20
15
10
5
0
-5
-10
Skill, Verification against ground stations
Skill, Verification against CMSAF satellite
better
ic0 REF
ic1
ic2
ic3
ic4
co0
co1
co2
co3
co4
co4 OPT
ICON versions

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Conclusions

- ICON-DE global radiation forecasts were verified during 4 month of 2016 over Germany.
- The verification included several ICON-DE versions, which differ by cloud-radiation parametrizations.
- One of the versions (co4) was optimized via calibration of 2 continuous parameters.
- Generally, ICON-DE overestimates the global radiation by 10-80 W/m^2. The RMSE varies between 80-140 W/m^2.
- COSMO cloudiness scheme shows better skill then ICON's.
- ICON-DE "co0" version shows very good results, having no bias on average.
- The calibration of 2 continuous parameters improved ICON-DE "co4" version (eliminating positive bias of 40 W/m^2).

- A code related to calculation of water contents and effective radiuses can be added to ICON