COSMO Priority Project: Clouds and Aerosols Improvements in ICON Radiation Scheme (CAIIR) – Phase 2 Project Plan

Version 4.0, 09.01.2022

Project duration: 03.2022 – 09.2023

Project leader: Harel Muskatel

Summary

This is a proposal for an extension of CAIIR priority project. The project started in March 2020 with a collaboration of IMS, RHM and DWD colleagues. We proposed the implementation of considerable new developments regarding cloud optics and related aerosols-radiation or aerosols-cloud interaction into ICON, and specifically into the new ecRAD radiation scheme recently introduced in ICON. Three main subjects were covered in the original proposal. The first is the introduction of new cloud droplets and ice particles optical properties (Hu & Stamness 1993, Fu 1996, 1998). The second is the introduction of new aerosols inputs to the radiation scheme: CAMS climatology, MacV2 climatology, CAMS forecasted aerosols and the 2D AOD advection scheme. The third is an investigation of the stochastic shallow convection scheme. On top of all of these, massive testing of the new code by comparison of model results with default setups and observations was planned. Some of the mentioned tasks were finished or significantly promoted, while few have not yet started or ought to be altered for this second phase. In this document, we will summarize the status of each updated task and evaluate the resources needed for its completion.

The major changes from the original project plan are:

A. Subtask 3.4 is added – we propose to implement the coupling of CAMS forecasted aerosols with the DeMott (2015) ice-nucleation scheme.

B. Task 7.1 (MACv2-Kinne(2013) aerosol climatology) is removed since the Kinne climatology was already implemented by Trang van Pham (DWD).

C. Task 10 (CALMO tuning) is removed due to a lack of resources.

D. Task 11 is added – we propose the Implementation of the Spectral Bin Microphysics scheme in ICON.

Motivation and project objectives

See first phase PP or find in:

http://www.cosmo-model.org/content/tasks/priorityProjects/caiir/default.htm

List of tasks:

1. Analysis and revision of ice optical properties based on Fu (1996, 1998) in ecRAD (Task 1)
2. Introduction of new liquid clouds optics based on Hu & Stamnes (1993) in ecRAD (Task 2)
3. Coupling of CAMS forecasted aerosols with cloud droplets and ice nucleation schemes (Task 3)
4. Implementation of CAMS prognostic aerosols 3D fields as input for ICON radiation scheme (Task 4)
5. Implementation of CAMS climatology aerosols as input for ICON radiation scheme (Task 5)
6. Improvements/testing of the 2D aerosols advection scheme in ICON (Task 6)
7. Implementation of Kinne (2013) aerosols climatology fields as input for ICON radiation scheme (Task 7)
8. Testing the radiation code using different aerosol inputs against experimental datasets for clear/cloudy sky conditions (Task 8).
9. Analysis/Revision of shallow convection scheme/SGS cloudiness in ICON radiation scheme (Task 9)
10. Systematic tuning (CALMO methodology) of the different ICON-RRTM versions for finding the best operative setup (Task 10)
11. Implementation of Spectral Bin Microphysics in ICON

Description of individual tasks

Task L: Project leadership

Estimated resources: 0.1 FTE per year

Task 1: Analysis and revision of ice optical properties based on Fu (1996, 1998) in ecRAD

See original PP.

Subtask 1.1 Calculations of modified bulk optical-properties of ice particles according to parametrizations based on Fu (1996, 1998, 2007) ready for being used with ecRADs LUT-format (done).

Subtask 1.2 Testing ecRAD with the new Fu-based parametrizations in real case studies (not started yet – waiting for completion of code modifications in ecRAD by Sophia Schafer (DWD)).

Deliverables:

(08.2023, 0.275 FTE: Harel 0.15, Alon 0.1, Yoav 0.025) Case studies and sensitivity analysis

FTEs altogether: Harel 0.15, Alon 0.1, Yoav 0.025

Estimated resources: 0.275 FTE

Status: Ongoing

Task 2: Introduction of new liquid clouds optics based on Hu & Stamnes (1993) in ecRAD

Subtask 2.1 Calculations of modified water droplets bulk properties parametrizations based on Hu and Stamnes (HS93) ready for being used by ecRAD LUT format (done).

Subtask 2.2 Testing ecRAD with the HS93 parametrizations in real case studies (not started yet – waiting for completion of code modifications in ecRAD by Sophia Schafer (DWD)).

Deliverables:

(08.2023, 0.275 FTE: Alon 0.1, Harel 0.15, Yoav 0.025) Case studies and sensitivity analysis

FTEs altogether: Alon 0.1, Harel 0.15, Yoav 0.025

Estimated resources: 0.275 FTE

Status: Ongoing

Task 3: Coupling of CAMS forecasted aerosols with cloud droplets and ice nucleation schemes

See original PP. In addition, we would like to propose yet another subtask (3.4). Through a second way to benefit from CAMS forecasted aerosols, we want to evaluate ice nuclei (IN) from forecasted dust fields according to the DeMott (2015) (DM2015) heterogeneous nucleation scheme. By this approach, IN number-concentration is derived from dust number- concentration and temperature in a computationally very cheap and straightforward way. The results are strikingly realistic, as was shown in COSMO PP $T^2(RC)^2$s final report.

These are the proposed subtasks (all not started yet):

Subtask 3.1 Coupling of CAMS forecasted aerosols to SK2006 method for cloud-droplets activation to produce a realistic cloud number-concentration compared with the default fixed value.

Subtask 3.2 Implementation of the mentioned R_{eff} and LWC calculation-method for convective clouds based on analytical, adiabatic LWC-profiles.

Subtask 3.3 Sensitivity analysis and documentation of the effects by means of case studies.

Subtask 3.4 Coupling of CAMS forecasted aerosols to DM2015 ice-nucleation scheme to produce a realistic IN number-concentration compared to the default fixed value.

Deliverables:

(08.2023, 0.2 FTE, Harel 0.2) Coupling of CAMS forecasted mixing ratios with SK2006 for QNC calculation.

(08.2023, 0.2 FTE, Pavel 0.2) Implementation of R_{eff} parametrization methods
(08.2023, 0.325 FTE, Pavel 0.1, Harel 0.2, Yoav 0.025) Sensitivity analysis and case studies performed

(08.2023, 0.2 FTE, Harel 0.2) Coupling of CAMS dust forecasted mixing ratios with DM2015 for IN number concentration calculation.

FTEs altogether: Harel 0.6, Pavel 0.3, Yoav 0.025

Estimated resources: 0.925 FTE

Status: Ongoing.

Task 4: Implementation of CAMS forecasted aerosols 3D fields as input for ICON radiation scheme

Status: Completed.

Task 5: Implementation of CAMS climatology aerosols as input for ICON radiation scheme

See original PP.

Subtask 5.1 Implementation of CAMS-based aerosol climatology as an external input file for the ecRAD scheme (Done). Preparing CAMS climatology for the RRTM scheme (Ongoing).

Subtask 5.2 Testing the new radiation code using the new aerosols CAMS-climatology against satellite observations and ground-based measurements such as BSRN stations (not yet started).

Deliverables:
(08.2023, 0.15 FTE: Poliukhov 0.1, Chubarova 0.05) Implementing the CAMS climatology in RRTM model

(08.2023, 0.25 FTE: Poliukhov 0.05, Chubarova 0.1, Shatunova 0.1) Testing and documentation of the effects compared with satellite observations and ground-based easements.

FTEs altogether: Poliukhov 0.15, Chubarova 0.15, Shatunova 0.1

Estimated resources: 0.4 FTE

Status: Ongoing.

Task 6: Improvements/testing of the 2D aerosols advection scheme in ICON

See original PP.

Subtask 6.1 Mineral dust optical depth source function. Done.

Subtask 6.2 Sea salt optical depth source function(Ongoing).

Subtask 6.3 Anthropogenic optical depth source function (not yet started).

Deliverables:
(08.2023, 0.25 FTE, Rieger 0.25) Sea salt optical depth source function

(08.2023, 0.25 FTE, Rieger 0.25) Anthropogenic optical depth source function

FTEs altogether: Daniel Rieger 0.5 FTE

Estimated resources: 0.5 FTE

Status: Ongoing.

Task 7: Implementation of the updated MACv2 aerosols climatology fields as input for ICON radiation scheme

Subtask 7.1 MACv2 aerosol climatology (Kinne et al., 2013) was lately introduced in the ICON model. This implementation was originally planned to be performed as part of CAIIR but was already completed by Trang van Pham (DWD). Therefore this sub-task is **removed** from the project's plan.

Subtask 7.2 We will test the efficiency of MACv2 aerosols by comparison with the prognostic CAMS aerosol as well as with the new CAMS aerosol climatology for clear sky conditions. For that purpose, an accurate comparison of ICON-radiation simulations with benchmark Monte-Carlo simulations will be performed.

Deliverables:

(08.2023, 0.2 FTE: Poliukhov 0.1, Chubarova 0.05, Rivin 0.05, Marina Shatunova 0.1, Julia Khlestova 0.05) The results of intercomparisons of different aerosol ICON simulations with the accurate off-line model simulations in clear sky conditions

FTEs altogether: Poliukhov 0.1, Chubarova 0.05, Rivin 0.05, Marina Shatunova 0.1, Julia Khlestova 0.05

Estimated resources: 0.35 FTE

Status: Ongoing.

Task 8: Testing the radiation code against experimental datasets

See original PP.

Subtask 8.1 Not yet started

Subtask 8.2 ongoing

Subtask 8.3 Not yet started.

Deliverables:

(08.2023, 0.2 FTE: Poliukhov 0.05, Chubarova 0.05, Rivin 0.05, Khlestova 0.05) The results of intercomparisons of different aerosol ICON simulations with the accurate experimental measurements in clear sky conditions

(08.2023, 0.4 FTE: Khlestova 0.15, Chubarova 0.05, Shatunova 0.15, Rivin 0.05) The assessment of the absolute and relative deviations between the forecasted and observed meteorological parameters due to the new cloud scheme and different aerosol inputs

(08.2023, 0.45 FTE: Poliukhov 0.1, Khlestova 0.1, Chubarova 0.05, Shatunova 0.15, Rivin 0.05) The results of an intercomparison of different aerosol ICON simulations with accurate experimental measurements in cloudy conditions. The assessment of the accuracy of implementation of new aerosol climatology to radiation fields and several meteorological parameters in the ICON model.

FTEs altogether: Poliukhov 0.15, Chubarova 0.15, Rivin 0.15, Shatunova 0.3, Khlestova 0.3

Estimated resources: 1.05 FTE

Status: ongoing.

Task 9: Analysis/Revision of shallow convection scheme and the related SGS cloudiness in ICON radiation scheme

Status: Completed.

Task 10: Systematic tuning (CALMO) of the different ICON-ecRAD versions for finding the best operative setup

(See CAIIR first phase project plan)

This task was not initiated, and we do not plan to follow the original plan any longer, because the required human and computational resources are larger than expected. Since, for that reason, a global-scale tuning is out of reach, we assume that in the next couple of years, expert tuning will still be the dominant approach in ICON.

Estimated resources: 0.0 FTE

Status: Not done. **Removed** from PP.

Task 11: Implementation of Spectral Bin Microphysics in ICON

In this second phase, we would like to propose a new task. The applied microphysical scheme significantly influences the radiation scheme. First, it determines the development and the lifetime of a cloud. Second, it determines its optical properties via the liquid water content and the effective radius.

Spectral Bin Microphysics (SBM) is a state-of-the-art microphysical scheme. It is included in several models worldwide, such as WRF, SAM, HUCM, JMA-NHM and the Goddard Cumulus Ensemble model. Due to the significant computer resources needed to run the scheme, it is usually applied for research purposes and the analysis of test cases. The implementation of SBM will provide similar possibilities in ICON in order to identify the pros and cons of the existing microphysical schemes with special regard to their impact on the simulation of radiation transport. We propose the following subtasks:

Subtask 11.1 Inclusion of the warm-phase SBM in ICON

At the first stage, we will include the warm-phase SBM. The schemes performance and quality will be analysed and compared with the already present 2M-scheme using idealized test cases.

Subtask 11.2 Inclusion of the mixed-phase SBM in ICON

At the second stage, we will include the mixed-phase SBM in the same manner as for the warm phase SBM before.

Deliverables:

(02.2022, 0.2 FTE, Pavel 0.2) Inclusion of the warm-phase SBM in ICON

(02.2023, 0.3 FTE, Pavel 0.3) Inclusion of the mixed-phase SBM in ICON

FTEs altogether: Pavel 0.5

Estimated resources: 0.5 FTE

Status: Not yet done.

Links to other projects or work packages

The work on ecRAD radiation scheme should be communicated with ECMWF and should be open for their use in the future. An open discussion with ECMWF scientists should be done during developments.

Risks and general comments

1. Close collaboration with DWD and KIT is needed to avoid duplicate work.
2. The work on ecRAD should be coordinated with ECMWF to avoid versions separation. The applicability in IFS should be considered.
3. The removal of existing error compensation can deteriorate the overall model performance at the first stage.
4. The FTE evaluation for each task is an approximation only.
5. A later, modified prioritization of tasks or subtasks according to available human resources and operational considerations cannot be excluded.

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Task	Contributing scientist(s)	FTE-years	FTE per person	Start	Deliverables	Date of delivery	Preceding tasks
1.1	Ulrich Blahak (DWD) Harel Muskatel (IMS)	-	-	-	Implementation of the new bulk parametrizations based on Fu in ecRAD	-	-
1.2	Alon Shtivelman (IMS) Pavel Khain (IMS) Harel Muskatel (IMS) Yoav Levi(IMS)	0.275	A-0.1 H-0.15 Y-0.025	01.03.2022	Case studies and sensitivity analysis	28.02.2023	1.1
2.1	Ulrich Blahak (DWD) Harel Muskatel (IMS)	-	-	-	Implementation of HS93 parametrization in the ecRAD framework	-	-

Task	Contributing scientist(s)	FTE-years	FTE per person	Start	Deliverables	Date of delivery	Preceding tasks
2.2	Alon Shtivelman (IMS) Pavel Khain (IMS) Harel Muskatel (IMS) Yoav Levi (IMS)	0.275	A-0.1 H-0.15 Y-0.025	01.03.2022	Case studies and sensitivity analysis	28.02.2023	2.1
3.1	Harel Muskatel (IMS)	0.2	H-0.2	01.03.2022	Coupling of CAMS forecasted mixing ratios with of SK2006 for QNC calculation	28.02.2023	-
3.2	Pavel Khain (IMS)	0.2	P-0.2	01.03.2022	Implementation of the mentioned R_{eff} and LWC calculation-method for convective clouds based on analytical, adiabatic LWC-profiles	28.02.2023	-
3.3	Pavel Khain (IMS) Harel Muskatel (IMS) Yoav Levi (IMS)	0.325	P-0.1 H-0.2 Y-0.025	28.02.2022	Sensitivity analysis and documentation of the effects by means of case studies	31.08.2023	-
3.4	Harel Muskatel (IMS)	0.2	H-0.2	01.09.2022	Coupling of CAMS dust forecasted mixing ratios with of DM2015 for IN number concentration calculation	31.08.2023	-
4.1	Harel Muskatel (IMS) Daniel Rieger (DWD)	-	-	-	Enabling the download of all CAMS fields from MARS (mars4icon_smi package), Implementing the CAMS 4D fields in the iconremap interpolation tool.	-	-
4.2	Harel Muskatel (IMS)	-	-	-	Implementation of the prognostic CAMS aerosols in ecRAD	-	-
4.3	Alon Shtivelman (IMS) Pavel Khain (IMS)	-	-	-	Sensitivity analysis and case studies performed	-	-
5.1	Poliukhov (RHM) Chubarova (RHM)	0.15	P-0.1 C-0.05	01.03.2022	Implementing the CAMS climatology in RRTM model	31.08.2022	-
5.2	Poliukhov (RHM) Chubarova (RHM)	0.25	P-0.05 C-0.1	01.09.2022	Sensitivity analysis and case studies performed	31.08.2023	-

Task	Contributing scientist(s)	FTE-years	FTE per person	Start	Deliverables	Date of delivery	Preceding tasks
	Shatunova (RHM)		S-0.1				
6.1	Daniel Rieger (DWD)	-	-	-	Mineral dust optical depth source function	-	-
6.2	Daniel Rieger (DWD)	0.25	D-0.25	01.03.2022	Sea salt optical depth source function	31.08.2022	-
6.3	Daniel Rieger (DWD)	0.25	D-0.25	01.09.2022	Anthropogenic optical depth source function	31.08.2023	-
7.1	Poliukhov (RHM) Chubarova (RHM) Rivin (RHM)	-	-	-	The implementation of Kinne MACv2 aerosol climatology in the ICON model	-	-
7.2	Poliukhov (RHM) Chubarova (RHM) Rivin (RHM) Khlestova (RHM) Shatunova (RHM)	0.35	P-0.1 C-0.05 R-0.05 S-0.1 C-0.05	01.03.2022	The results of intercomparisons of different aerosol ICON simulations with the accurate off-line model simulations in clear sky conditions	31.08.2023	-
8.1	Poliukhov (RHM) Chubarova (RHM) Rivin (RHM) Khlestova (RHM)	0.2	P-0.05 C-0.05 R-0.05 K-0.05	01.03.2022	The results of intercomparisons of different aerosol ICON simulations with the accurate experimental measurements in clear sky conditions	01.03.2023	-
8.2	Khlestova (RHM) Chubarova (RHM) Shatunova (RHM) Rivin (RHM)	0.4	K-0.15 C-0.05 S-0.15 R-0.05	01.09.2022	The assessment of the absolute and relative deviations between the forecasted and observed meteorological parameters due to new cloud scheme and different aerosol inputs	31.08.2023	-
8.3	Khlestova (RHM) Chubarova (RHM) Shatunova (RHM) Rivin (RHM)	0.45	K-0.1 C-0.05 S-0.15 R-0.05	01.09.2022	The results of intercomparison of different aerosol ICON simulations with the accurate experimental measurements in cloudy conditions. The assessment of the accuracy of implementation of new aerosol climatology to radiation fields	31.08.2023	

Task	Contributing scientist(s)	FTE-years	FTE per person	Start	Deliverables	Date of delivery	Preceding tasks
	Poliukhov (RHM)		P-0.1		and several meteorological parameters in the ICON model		
9.1	Pavel Khain (IMS)	-	-	-	Testing the stochastic shallow convection parametrization	-	-
9.3	Pavel Khain (IMS)	-	-	-	Precipitation from the stochastic shallow convection parametrization	-	-
10.1	Pavel Khain (IMS)	-	-	-	Parameters sensitivity	-	-
10.2	Pavel Khain (IMS)	-	-	-	Tuning the cloud-radiation scheme	-	-
11.1	Pavel Khain (IMS)	0.2	P-0.2	01.03.2022	Inclusion of the warm-phase SBM in ICON	31.08.2022	-
11.2	Pavel Khain (IMS)	0.3	P-0.3	01.09.2022	Inclusion of the mixed-phase SBM in ICON	31.08.2023	-
L	Harel Muskatel (IMS)	0.15	H-0.15	01.03.2022	Project leadership	31.08.2023	
All		**4.425**		**01.03.2022**		**31.08.2023**	

Estimated resources needed COSMO-year:

	Mar2022-Aug2022	Sep2022-Aug2023
Daniel Rieger	**0.25 FTEs**	**0.25 FTEs**
Pavel Khain	**0.30 FTEs**	**0.5 FTEs**
Harel Muskatel	**0.35 FTEs**	**0.7 FTEs**
Alon Shtivelman	**0.1 FTEs**	**0.1 FTEs**
Yoav Levi	**0.025 FTEs**	**0.05 FTEs**
Poliukhov	**0.2 FTEs**	**0.2 FTEs**
Chubarova	**0.1 FTEs**	**0.25 FTEs**
Shatunova	**0.15 FTEs**	**0.35 FTEs**
Khlestova	**0.1 FTEs**	**0.25 FTEs**
Rivin	**0.05 FTEs**	**0.15 FTEs**
Total:	**1.625 FTEs**	**2.8 FTEs**