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

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Summary

During the last year, a new version of RRTM has been introduced into ICON, which is the new ECMWF radiation scheme for IFS, ecRAD (Hogan and Bozzo, 2018). Based on this preparation, a window for further development and testing is now open. In this project plan, we propose the implementation of considerable new developments regarding cloud optics and related aerosols-radiation or aerosols-cloud interaction into ICON, so as to be active in ecRAD. The main part of this development has already been done during PP $T^2(RC)^2$ and is now a part the COSMO model. Although related extensions have even been transferred to the current version of RRTM in ICON (henceforth referred to as RRTM), ecRAD has not yet been extended accordingly. Further, new sources of associated aerosol data are not yet accessible for ICON. Moreover, we want to investigate to what extend the statistical information of a stochastic shallow convection scheme, which is already present in a sub-development branch of ICON, can be integrated into the formulation of cloud-radiation interaction. Finally, we also intend to perform massive testing of the new code by comparison of model results with observations.

Motivation and project objectives

Radiation transfer models are one of the main elements in NWP models, which can drastically contribute to heating and cooling rates in all levels of the atmosphere. This can critically change the dynamics in the atmosphere and dramatically affect the model skills. On the other hand, radiation schemes are extremely complicated due to the large amount of gases, hydrometeors and aerosol species being involved in radiation-transfer processes. For each of these air components, the governing optical properties need to be parametrized in each considered spectral interval of the model as a function of proper bulk properties of these species valid for a grid box, which is primarily the effective radius.

During the years 2015-2019, the radiation scheme in the COSMO model was updated as part of a Priority Project (PP) Testing and Tuning of the Revised Cloud Radiation Coupling $T^2(RC)^2$. The revision included updating the optical properties of water droplets Hu & Stamnes (1993) and ice particles Fu (1996, 1998).. The new parametrizations expanded the range of validity, namely towards larger dimensions of the included hydrometeors, up to the size of rain and snow particles. These parametrizations have been implemented in the official radiation schemes for both COSMO (the Ritter & Geleyn, 1992) and ICON (RRTM). Other related improvement, up to now only implemented in COSMO, includes the utilization of MACv2 aerosols climatology (Kinne 2013), prognostic ICON-ART dust and the prognostic CAMS aerosols as a direct effect in the radiation scheme. This aerosol information has also been employed as an input for the process of water and ice nucleation, representing an indirect aerosol-effect on radiation transfer. The project also included a new water droplets effective radius parametrization and a revised formulation of the impact of sub-grid scale (SGS) cloud generation on radiation processes. Finally, computational optimizations, like the Monte-Carlo Spectral Integration (MCSI) scheme, have been implemented into COSMO in order to reduce the run-time of radiation calculations. The respective code and its new features have thoroughly been tested and tuned against ground based and satellite measurements, performed in Israel, Germany and Russia under different weather conditions. Through this, a positive impact of the new development on net radiation fluxes and near-surface temperatures could be demonstrated. During the second phase of $T^2(RC)^2$ the new cloud optics have also been implemented into the currently operational radiation scheme of ICON (RRTM), including the new formulation of the SGS cloud-impact. Like in COSMO, all the mentioned improvement together has proven to cause better radiation fluxes also in ICON. However, the new ecRAD code, which is now available in ICON, has not yet been adapted to these promising developments. Moreover, for liquid clouds, the effective radius calculation in the ICON code needs to be updated, as it has already been done in COSMO.

The first topic of this project concerns with cloud optics. As mentioned earlier, new ice optical properties parametrizations following Fu (1996, 1998) have already been introduced and tested in ICON-RRTM. In ecRAD the ice optics are also based on the same author (Hogan and Bozzo, 2018), but they are implemented with a different spectral averaging technique. Now we wish to analyse the different schemes and to define the best-suited solution for ICON-ecRAD. Regarding the water droplets optical properties, ecRAD uses the SOCRATES package (Hogan and Bozzo, 2018 and references therein) while, in ICON, we lately introduced the Hu & Stamnes (1993) parametrization. We wish to implement in the ecRAD framework due to several advantages such as a single simplistic formulation for the whole spectrum (long and short wave intervals) and an advanced spectral integration suitable for NWP models. The new proposed optical properties are now parametrized using formulas that uses effective radius (R_{eff}) or aspect ratio (AR) as a parameter. However the future plan for ecRAD is using look-up table (LUT) approach proposed by Robin Hogan (ECMWF). Therefore a transformation from formulas to LUT is needed.

The cloud droplets bulk optical properties are defined by the effective radius R_{eff} . For the use in ecRAD, R_{eff} is treated either as a constant or, using the ECHAM5 method, as a function of liquid water content and cloud number concentration. We plan on implementing a prognostic approach, which was tested in COSMO, where the Segal & Khain (2006) activation scheme is used to define the cloud number concentration from prognostic CAMS aerosols number concentration and effective updraft speed. This prognostic cloud number concentration is later used to define a realistic R_{eff} using the Khain et al. (2019) scheme.

The second goal of this project is to introduce new aerosols inputs for radiation, suited for the operational ICON mode. Currently the Tegen (1997) climatology is employed in ICON operational setup. These monthly averaged optical depth values of aerosols are used to define a number concentration profile, which, consequently, is not affected by the model dynamics. It is a well-known fact that aerosols are a major element in both radiative transfer and for cloud formation. The direct effect on radiation can be easily seen in dust outbreaks and volcanic ash eruptions, but even on regular conditions aerosols concentration can have large day-to-day variability imposing large errors when climatological averages are used. This is the reason that in COSMO model we added three new aerosols inputs in addition to the old climatologies of Tanre (1983) and Tegen (1997). First is the CAMS prognostic aerosols provide a 5-day lead-time global forecast for the 3D mixing ratios of five types of aerosols, which are divided into eleven aerosols tracers with an hourly temporal resolution. As the CAMS aerosols optical properties are already a part of ecRAD, their implementation can be done straightforwardly. The second is the global ICON-ART dust forecast, which is now running semi-operationally twice a day at DWD. These data have been made available for COSMO as well. The third is the most up to date aerosols climatology available, namely the MACv2 by Kinne (2013). In the same way, these data should be integrated into ICON NWP-runs and can then be attached to ecRAD as well. Lately, a simplified and fast 2D prognostic scheme for mineral dust has been developed by Günther Zängl (DWD), using the Tegen (1997) climatology as initial conditions. In the course of our project, we aim to test this method and further develop it for the application to other aerosols species and different initial conditions. One or more of the mentioned aerosols inputs can also be used as condensation nuclei for the microphysical scheme using Segal & Khain method, which can improve precipitation rates and can improve the effective radius calculation for the radiation-indirect effect. Notice, that the prognostic ART component usually can’t be active in NWP runs with ICON. Hence, ICON-ART data, which so far are restricted to mineral dust only, need to be provided as offline products as well. However, DWD plans to include also sea salt and dust from vegetation burn in the next future (project PERMASTROM).

Another target of this project deals with the shallow convection parametrization and its effect on the radiation. Shallow convection (SC) parametrization plays a crucial role in the evolution of simulated boundary layer structure. This effect and the interaction with the grid scale dynamics have a significant impact on cloudiness and precipitation. For example, over the eastern Mediterranean, COSMO SC parametrization reasonably well mixes the boundary layer in fair weather, but dries out the lower levels and thus prevents grid scale precipitation in unstable situations. As part of this project we plan to analyze the behavior of the recently developed stochastic shallow convection parametrization (Sakradzija et al. 2016, 2018), focusing on the boundary layer structure. This parametrization couples a stochastic model based on a canonical ensemble of shallow cumuli to the Eddy-Diffusivity Mass-Flux scheme. The moist-convective area fraction is perturbed by subsampling the distribution of sub-grid convective states, yielding fluctuations around the quasi-equilibrium state of shallow cumulus ensemble. Unlike the deterministic approach, this parameterization reproduces the average and higher order statistics of the shallow cumulus case adequately. Using this parametrization, we aim to implement and verify a detrainment-based cloud cover estimation, since cloud cover plays an important role in the radiation transfer. We further plan to utilize the sub-grid variability of the stochastic parametrization to better estimate the sub-grid microphysical rates. This may have a positive impact on the estimation of precipitation from shallow convection and on the dynamics of the boundary layer. We plan to test this parametrization on real cases, defining its weaknesses and the advantages over the default Tiedke-Bechtold scheme. This product will be verified versus observations in real cases, and it will be compared to idealized LES simulations of cloud cover in BOMEX case. Precipitation from shallow convection can have an important effect on the boundary layer dynamics. In order to estimate the microphysical rates (such as autoconversion, accretion and evaporation rate) a sub-grid PDF of cloud and rainwater content is needed (Larson et al. 2015, Cogan et al. 2014). We plan to utilize the sub-grid variability of the stochastic parametrization to estimate this PDF. If successful, this may have a positive impact on the estimation of precipitation from shallow convection, compared to the current method used in Tiedke-Bechtold scheme.

The last and not less important part of our suggested project deals with testing. Preliminary results (Poliukhov et al., 2018) show that the Tegen aerosol climatology (1997) provides too high aerosol loading. At the same time, the sensitivity studies revealed high impact of aerosol on temperature near surface (Chubarova et al., 2018). The new aerosol dataset proposed by Kinne et al. (2013) is considered to better describe real aerosol loading (Mueller and Träger-Chatterjee, 2014). We plan to verify both the computationally cheap new MACV2 aerosol climatology (Kinne et al. (2013), the new CAMS climatology as well as the prognostic CAMS aerosol against the data of Moscow State University Meteorological Observatory. This dataset contains different aerosol characteristics from its AERONET sun-photometer (Chubarova et al., 2011), hourly visual cloud observations, longwave and shortwave components of net radiation according to the CNR4 KIPP@Zonnen radiometer, etc. (www.momsu.ru). We also wish to test the ICON algorithm in different clear sky conditions (various solar elevation, surface albedo, aerosol loading, etc.). If necessary, another dataset is possible to apply from the AERONET and WRDC archives. We propose to provide verification in clear sky conditions for checking both the radiative code and the different aerosol inputs. We also propose to test the ICON shortwave code with different aerosol loading against other accurate reference radiation transfer (RT) codes.

For studies in cloudy conditions, we plan to use different types of radiative and cloud /aerosol microphysical measurements - performed at the Lindenberg Observatory (Germany) as well as data from the Moscow State University (MSU) observatory and possibly from some other supersites - for checking the new cloud algorithm in the ecRAD radiation scheme. A similar analysis had been applied before with respect to the radiation code of COSMO, which still reveals differences between simulated and measured water vapour profiles at high altitudes of the troposphere (Chubarova et al, 2018, SPIE). Further, it is planned to estimate the sensitivity of the most important meteorological forecast quantities to the new aerosol/cloud input in ecRAD and to assess the change in forecast quality due to all the related measures.

Massive and systematic testing and tuning of the new scheme and its multiple aerosols and cloud options should be performed under different weather conditions for the future decision making for the operational setup in ICON.

Actions proposed

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. Implementation of Segal & Khain (2006) droplets activation scheme for the effective radius calculation in ICON radiation (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)

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

In $T^2(RC)^2$ new ice particles optical properties were introduced both in COSMO and ICON radiation schemes. Single scattering albedo, asymmetry factor, extinction coefficient and forward scattered fraction based on Fu (1996, 1998, 2007) were calculated. The calculation was based on the single particle data by Fu but instead of using the in-situ particle size distributions (PSD) used by Fu, we generated 7500 PSDs based on the generalized gamma distribution function allowing the extension of the effective size validity range from 70 to 300 micrometres. Using these functions and a wise spectral averaging technique we calculated the bulk optical properties as a function of the effective size of the needle shape particles or its aspect ratio in the case of the asymmetry factor parametrization. The parametrization was based on an ansatz of the form: $f(x)=\sum_{i=0}^{n} a_i x^i / \sum_{i=0}^{m} b_i x^i$ where *f* can be each of the optical properties and *x* is either the effective size or the aspect ratio and it is asymptotically stable even for particles as large as a few centimeters. The mentioned spectral averaging was adapted for both COSMO and ICON spectral intervals and was separately tested and verified extensively. ecRAD scheme also uses Fu's ice parametrization but with different spectral averaging and bulk optical properties parametrizations.

Therefore, we propose the following subtasks:

Subtask 1.1 Implementation of modified ice particles bulk properties parametrizations based of Fu (1996, 1998, 2007) into ecRAD by transferring the formulas into LUT. Analyzing and comparing the results for both parametrizations and their effects on cloud optical depth. Testing the effects of choosing aspect ratio diagnostics vs. effective radius on the asymmetry factor.

Subtask 1.2 Testing both ICON-RRTM and ecRAD Fu based parametrizations using real case studies/Idealized runs including cirrus clouds. Statistical analysis of the radiative sensitivity to the new parametrization using global ICON runs especially focusing on polar areas.

Deliverables:

(02.2021, 0.25 FTE, Harel 0.2, Uli 0.05) Implementation of the new bulk parametrizations based on Fu in ecRAD

(02.2021, 0.2 FTE, Pavel 0.15, Alon 0.1) Case studies and sensitivity analysis

FTEs altogether: Harel 0.2, Uli 0.05, Pavel 0.15, Alon 0.1

Estimated resources: 0.5 FTE

Status: Not yet done.

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

In 1993, Hu and Stamnes (HS93) published their work on liquid clouds optics based on Mie calculations. They claimed that cloud optical properties depend mainly on equivalent effective radius and liquid water content, while the details of the cloud droplets size distribution can be neglected. Based on these assumptions, the authors had computed extinction coefficient, asymmetry factor and single scattering- albedo for 74 narrow wavelengths between 0.29 μm – 150 μm; and they parameterized these optical properties for three droplets size bins in the range of 2.5 μm – 60 μm. Using the HS93-parametrizations, we have already recalculated the mentioned optical properties for COSMO and ICON spectral intervals as part of PP $T^2(RC)^2$. With the new parametrizations, we could extend the validity range of their application, including now also larger liquid particles. The current ecRAD implementation, on the other hand, has two alternatives. The first is the parametrization based on Slingo (1989) for shortwave, and the one of Lindner and Li (2000) for longwave (SLL). The second is based on the SOCRATES Suite of Community Radiation Codes (Edwards and Slingo, 1996).

Therefore, we propose the following subtasks:

Subtask 2.1 Implementation of HS93 parametrization in the ecRAD framework by transferring the formulas into LUT. The spectral intervals in ICON and ecRAD should be similar but in case of differences the optical properties should be calculated to match ecRAD spectral bands.

Subtask 2.2 Radiation and surface temperature sensitivity analysis for the use of each of the mentioned methods (SLL, SOCRATES and HS93) under different cloud types conditions. Real case studies performed comparing the methods and evaluating the model performance in different weather situations against ground based measurements. The domain will be discussed at later time.

Deliverables:

(02.2021, 0.25 FTE, Harel 0.2, Uli 0.05) Implementation of HS93 parametrization in the ecRAD framework

(02.2021, 0.3 FTE, Alon 0.1, Pavel 0.15, Yoav 0.05) Sensitivity analysis and case studies performed

FTEs altogether: Harel 0.2 FTE, Uli 0.05 FTE, Pavel 0.15 FTE, Alon 0.1 FTE, Yoav 0.05 FTE

Estimated resources: 0.55 FTE

Status: Not yet done.

Task 3: Implementation of Segal & Khain droplets activation scheme for the effective radius calculation in ICON radiation

In Segal & Khain, 2006 (SK), cloud droplets number concentration (QNC) at cloud base is determined by aerosols particle size distribution, number concentration, mode radius, geometric standard deviation (σ_g) and updraft speed at cloud base. The values can be extracted by parametrization or from 4D look-up tables. In the course of PP $T^2(RC)^2$ the look-up table version was applied for COSMO. The aerosols input can be either the Tegen AOD climatology using a fixed mode radius and σ_g (allowing the 4D table to be reduced to a 2D table) and using the AOD value to define an exponential decay for the aerosols number concentration. Alternatively, the CAMS 3D prognostic aerosols mixing ratios are used to define the number concentration of the different aerosols at each grid point. In this option some averaged "effective" aerosol mode radii and σ_g are calculated at each point to account for all hydrophilic tracers available in the CAMS forecast. The number concentration of droplets is used for the evaluation of the effective radius of water clouds, which effects the radiation fluxes (the so-called "indirect radiative effect of aerosols"). There are two ways of calculating the droplet effective radius from the droplet number concentration. First is using the formula of liquid water content (LWC) to QNC power law $R'_{eff}=c_1\left(\frac{LWC}{QNC}\right)^{c_2}$ where c_1, c_2 are determined from the particle size distribution used in the microphysical scheme. The second one is valid for sub-grid scale shallow convection clouds where an analytical adiabatic LWC is used to calculate R_{eff} using the formula $R'_{eff}=1.15\left(\frac{LWC_{ad}}{QNC}\right)^{1/3}$. The actual LWC is calculated from R_{eff} using the same formula with the calculated R'_{eff} and QNC (Khain et al. 2019). The new cloud number concentration is also used in the 1-mom microphysical scheme for auto-conversion of cloud water to precipitation. Using this formula can dramatically effect precipitation compared to the default fixed cloud number concentration. We propose using the same approach in ICON model.

Therefore, we propose the following subtasks:

Subtask 3.1 Implementation of SK method for cloud droplets activation in ICON 1-mom microphysics scheme using both Tegen/CAMS climatology and also CAMS prognostic aerosols to produce a realistic cloud number concentration compared with the default fixed number concentration.

Subtask 3.2 Implementation of R_{eff} calculation methods from the prognostic cloud number concentration as described above and applying the result in ecRAD radiation scheme.

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

(02.2022, 0.5 FTE, Harel 0.4, Uli 0.1) Implementation of SK method in ICON 1-mom scheme with different aerosols inputs

(02.2022, 0.2 FTE, Pavel 0.2) Implementation of R_{eff} parametrization methods using the calculated prognostic cloud droplets number concentration

(02.2022, 0.35 FTE, Alon 0.1, Pavel 0.1, Harel 0.1, Yoav 0.05) Sensitivity analysis and case studies performed

FTEs altogether: Harel 0.5, Pavel 0.3, Alon 0.1, Uli 0.1, Yoav 0.05

Estimated resources: 1.05 FTE

Status: Not yet done.

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

The Copernicus Atmosphere Monitoring Service (CAMS) is an ECMWF project, which provides air quality analysis and forecast including aerosols and other tracers. The model is based on IFS but with a coarser spatial resolution. The output forecast lead time is 5 days with an hourly temporal resolution and includes the 3D mixing ratios of 11 aerosols tracers: 3 size bins of mineral dust, 3 size bins of sea salt, sulphate, hydrophobic and hydrophilic tracers of both black carbon and organic matter. These aerosols tracers are used as both direct and indirect effects on radiation in the COSMO model in an experimental version running twice a day in IMS showing positive results. The same can be achieved in ICON and more easily in ecRAD framework since the model is already coupled to CAMS climatology input so no optical properties adaptation to this version is needed. At first step, the CAMS data will be used only for cases where the used boundary data from IFS has the same 137 model levels as in CAMS.

Therefore, we propose the following subtasks:

Subtask 4.1 Enabling the download of all CAMS aerosols tracers as additional fields or files via MARS archive as part of the `mars4icon_smi` pre-processing package. Implementing the CAMS 4D fields in the `iconremap` interpolation tool to allow the interpolation of the aerosols tracers in both space and time. As was done in COSMO, the aerosols can be interpolated as "boundary conditions" but for the entire domain which can be either global or LAM.

Subtask 4.2 Implementing the CAMS 4D fields in ecRAD framework as a direct effect for the radiation as it was done with CAMS climatology. These fields will also be used for the indirect effect via cloud formation as part of task 3.

Subtask 4.3 Sensitivity analysis and documentation of the effects on case studies.

Deliverables:

(02.2022, 0.1 FTE, Harel 0.05, Daniel R. 0.05) Enabling the download of all CAMS fields from MARS (`mars4icon_smi` package), implementing the CAMS 4D fields in the `iconremap` interpolation tool.

(02.2022, 0.2 FTE, Harel 0.2) Implementation of the prognostic CAMS aerosols in ecRAD

(02.2022, 0.2 FTE, Alon 0.1, Pavel 0.1) Sensitivity analysis and case studies performed

FTEs altogether: Harel 0.25, Pavel 0.1, Alon 0.1, Daniel R. 0.05

Estimated resources: 0.5 FTE

Status: Not yet done.

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

Based on the combination of short-range forecast and reanalysis (CAMSiRA) of the CAMS model, a new monthly aerosol climatology for the period 2003-2014 was developed at ECMWF (Bozzo et al., ECMWF 801 Technical report, 2017). The new climatology suggests a different AOD 2D distribution of tracers mentioned in the previous sections and also different vertical distributions compared with previous climatologies. The new application showed improvements in both SW and LW spectral intervals mostly for local biases compared to the previous operational Tegen (1997) climatology that was used in IFS model.

Therefore, we propose the following subtasks:

Subtask 5.1 Implementation of CAMS-based aerosol climatology as an external file input for ICON model. Any further work on radiation-aerosols interaction is unnecessary, since this interaction is already described in ecRad.

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.

Deliverables:

(02.2021, 0.2 FTE: Poliukhov 0.05, Chubarova 0.05, Shatunova 0.1) Implementing the CAMS-based aerosol climatology fields as an external parameters file for ICON model

(02.2022, 0.35 FTE: Poliukhov 0.1, Chubarova 0.1, Shatunova 0.1, Khlestova 0.05) Testing and documentation of the effects compared with satellite observations and ground based easements.

FTEs altogether: Poliukhov 0.15, Chubarova 0.15, Shatunova 0.2, Khlestova 0.05

Estimated resources: 0.55 FTE

Status: Not yet done.

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

ICON has an option for a 2-dimensional prognostic aerosol scheme. For this, the horizontal wind components are vertically averaged ($v'_{H,j}$) and used to calculate advection of the 2-dimensional aerosol optical depth $\psi_j(x,y)$. In addition, the scheme contains also simple source functions $S_{e,j}$ (emissions) and sink terms $S_{w,j}$ (wet deposition). For the aerosol optical depth a relaxation to its climatological $\psi_{clim,j}$ value on a certain time scale $\tau_{clim,j}$ is performed. The following equation is solved for each of the five aerosol optical depth species j :

$$\frac{\partial \psi_j(x,y)}{\partial t} = v'_{H,j} \nabla \psi_j(x,y) + S_{e,j} + S_{w,j} + \frac{(f_{clim,j} \psi_{clim,j}(x,y) - \psi_j(x,y))}{\tau_{clim,j}}$$

With the tuning factor $f_{clim,j}$, the target value of the climatological AOD can be modified. The aim of this task is to improve the representation of the source functions $S_{e,j}$. Consequently, the subtasks can be structured according to the different aerosol species.

Subtask 6.1 Mineral dust optical depth source function

Based on brittle fragmentation theory, Kok (2011a) predicts that the size distribution of emitted mineral dust particles does not depend on the wind speed (Kok, 2011b) which is in good agreement with field measurements. This is in contrast to commonly used mineral dust emission parameterizations that predict such a dependency based on wind tunnel measurements. The prediction of this dependency makes commonly used emission parameterizations like the one used for ICON-ART (Rieger et al., 2017) computationally expensive. Following their previous studies, Kok et al. (2014) present a computationally efficient parameterization for mineral dust emission fluxes. This parameterization will be implemented as a source function for mineral dust. Mie calculations will be performed to derive the dust optical depth source function $S_{e,dust}$.

Subtask 6.2 Sea salt optical depth source function

In their review publication, Grythe et al. (2014) summarize the state of the sea spray aerosol (SSA) source functions. They compare 21 commonly used parameterizations to different measurement datasets representing the various conditions under which sea salt aerosol particles are emitted globally. In general, the source functions depend on 10-m wind speed, sea surface temperature and, in some cases, on the salinity of the ocean. In this subtask, one of these source functions will be chosen to be implemented into ICON. The decision which function will be implemented will be based on computational efficiency and the quality of the results. Using Mie calculations, a SSA optical depth source function $S_{e,ssa}$ can be derived.

Subtask 6.3 Anthropogenic optical depth source function

Finding an adequate source function for aerosol optical depth from anthropogenic sources will be a major challenge due to the multitude of complex non-linear processes involved in the formation of anthropogenic aerosol particles. These processes include the emission of primary particles and gaseous precursors, atmospheric chemistry, secondary aerosol formation and the interaction with organic compounds. The aim is to find an anthropogenic aerosol optical depth source function $S_{e,anth}$ based on parameters which are available within ICON like land use fraction (e.g., urban, agricultural, etc.) in combination with a daily cycle. Alternatively, the usage of an emission climatology will be explored.

Deliverables:

(02.2022, 0.2 FTE, Rieger 0.2) Mineral dust optical depth source function

(02.2022, 0.2 FTE, Rieger 0.2) Sea salt optical depth source function

(02.2022, 0.5 FTE, Rieger 0.5) Anthropogenic optical depth source function

FTEs altogether: Daniel Rieger 0.9 FTE (0.45 per year)

Estimated resources: 0.9 FTE

Status: Not yet done.

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

Subtask 7.1 Since aerosol properties have a noticeable effect on air temperature, their adequate description will improve the quality of weather forecast. The cheapest way to do is to use the state of the art MACv2 aerosol climatology (Kinne et al., 2013) which has been developed recently at Max Planck Institute. This modern aerosol climatology will be implemented in ICON radiation scheme as an alternative to the current default scheme which uses the Tegen (1997) climatology.

Subtask 7.2 We will test its efficiency by comparisons with the prognostic CAMS aerosol as well as with the new CAMS aerosol climatology. For clear sky conditions, the accurate comparison of ICON radiative simulations will be made in the off-line regime for the same statistics with benchmark Monte-Carlo simulations.

Deliverables:

(02.2021, 0.3 FTE: Poliukhov 0.15, Chubarova 0.05, Rivin 0.05, Khlestova 0.05) The implementation of Kinne MACv2 aerosol climatology in the ICON model.

(02.2022, 0.25 FTE: Poliukhov 0.1, Chubarova 0.1, Rivin 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 0.25, Chubarova 0.15, Rivin 0.1, Khlestova 0.05

Estimated resources: 0.55 FTE

Status: Not yet done.

Task 8: Testing the radiation code against experimental datasets

Subtask 8.1 The verification of the output results (aerosols, radiation, main meteorological parameters) after application of the updated Kinne (MACv2) climatology and CAMS aerosol fields from the ECMWF as part of the Copernicus Program in clear sky conditions against different aerosol sites in different meteorological conditions. The baseline site for comparisons is the dataset of Meteorological Observatory of Moscow State University (37.5E, 55.7N) for different geophysical conditions (solar elevation, aerosol properties, surface albedo, and trace gases amount (water vapor, ozone). The main instruments, which will be used, are AERONET CE-318 sun photometer (aerosol properties, column water vapor), Kipp@Zonen net radiometer CNR-4 (upward and downward longwave, shortwave fluxes, and surface albedo), standard meteorological observations (temperature, ground water vapor pressure, and relative humidity), and satellite retrievals (total ozone). The period for the comparisons will cover the previous years since 2018 and the future observations. The total number of cases will be about 15-25 depending on the availability of stable (at least 4-5 hours) clear sky conditions both in model output and real observations.

Subtask 8.2 For cloudy conditions, we will test the new ecRAD radiation scheme (including the account for non-direct aerosol effects) against the cloud and radiation data of the Lindenberg and Moscow Observatories. For this purpose, we plan to use different, accurate measurements of shortwave and longwave radiation where the selected cases will cover preferably the range of one full year.

Subtask 8.3 Further, we want to evaluate the sensitivity of important forecasted meteorological parameters (air temperature, for example, and some others) to the aerosol/cloud characteristics applied in the radiative scheme. Finally, we try to assess the influence of the implemented modifications (including the consideration of various aerosol input) on the absolute and relative forecast error.

Deliverables:

(02.2021, 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

(02.2022, 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 new cloud scheme and different aerosol inputs

(02.2022, 0.5 FTE: Poliukhov 0.1, Khlestova 0.1, Chubarova 0.1, Shatunova 0.15, Rivin 0.05) 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 and several meteorological parameters in the ICON model.

FTEs altogether: Poliukhov 0.15, Chubarova 0.2, Rivin 0.15, Shatunova 0.3, Khlestova 0.3

Estimated resources: 1.1 FTE

Status: Not yet done.

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

This task deals with the shallow convection parametrization and its effect on the radiation. This parametrization effects the cloud cover estimation especially for partial cloudiness conditions and therefore dramatically effects the atmosphere opacity and the total energy budget. Recently, a stochastic parametrization of shallow cumulus was developed and implemented in a separate branch of ICON (Sakradzija et al. 2016, 2018). At the moment, the scheme has not shown benefits and had some stability issues compared to the default scheme. Nevertheless, further development is still ongoing in DWD and we plan to test this parametrization on real cases. The detrainment approach will be implemented in this parametrization to deduce the cloud cover of shallow convection. This product will be verified versus observations and compared to idealized LES simulations. We plan to utilize the sub-grid variability of the stochastic parametrization to estimate the microphysical rates, which may have a positive impact on the estimation of precipitation from shallow convection.

Therefore, we propose the following subtasks:

Subtask 9.1 Testing the stochastic shallow convection parametrization

Stochastic shallow convection parametrization will be verified against observations.

We plan to focus on profiles verification against soundings. The exact verification domains and periods will be defined depending on the available computer resources. This will allow us to define the weaknesses and the advantages of the stochastic parametrization over the default Tiedke-Bechtold scheme.

Subtask 9.2 Estimating the cloud cover from the stochastic shallow convection parametrization

Similarly to the Tiedke-Bechtold scheme, the detrainment approach will be implemented in the stochastic shallow convection parametrization to deduce the cloud cover of shallow convection. This product will be verified versus available observations (still not defined) in real cases. Again, the exact verification domains and periods will be defined depending on the available computer resources. In addition, the scheme will be simulated in idealized (preferably BOMEX or RICO) fair weather situations, and compared to idealized LES simulations of cloud cover. Analyze the two cloud cover parameterization in ICON, tune and to determine and the best scheme for different geographical domains.

Deliverables:

(02.2021, FTE: Pavel 0.2) Testing the stochastic shallow convection parametrization

(02.2021, FTE: Pavel 0.2) Estimating the cloud cover from the stochastic shallow convection parametrization

FTEs altogether: Pavel 0.4

Estimated resources: 0.4 FTE

Status: Not yet done.

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

Following the project, the cloud-radiation scheme will include many dependencies whose contributions will be described by tens of new parameters. Besides, different options will be activated using several logical switches. First, we will perform sensitivity experiments to identify the parameters and logical switches, which have particularly high influence on the radiative fluxes in the model. Second, several most important logical switches combinations (cloud-radiation scheme configurations) will be selected, and the relevant parameters for each of the combinations will be tuned against global radiation data from surface stations and satellite data. The exact verification domains and periods will be defined depending on the available computer resources. For example, a full parameter tuning can be performed as a first step on the ICON-LAM scale (i.e. ICON-D2 domain) and then can be tested on a global scale when only the aerosols climatology is modified.

Therefore, we propose the following subtasks:

Subtask 10.1 Parameters sensitivity

At first stage, we will perform sensitivity experiments to identify the parameters and logical switches which have particularly high influence on the radiative fluxes in the model. The exact simulations domains and periods for these sensitivity tests will be defined depending on the available computer resources.

Subtask 10.2 Tuning the cloud-radiation scheme

At the second stage, several most important logical switches combinations of the cloud-radiation scheme will be selected, and the relevant parameters for each of the combinations will be tuned against global radiation data from surface stations and satellite data. The exact verification domains and periods will be defined depending on the available computer resources.

Deliverables:

(02.2022, 0.15 FTE, Pavel 0.15) Parameters sensitivity

(02.2022, 0.15 FTE, Pavel 0.15) Tuning the cloud-radiation scheme

FTEs altogether: Pavel 0.3

Estimated resources: 0.3 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. Allocation of computer resources for automatic tuning exercise.
2. For each new development the computational cost needs assessment.
3. A close collaboration with DWD and KIT is needed to avoid duplicate work.
4. The work on ecRAD should be coordinated with ECMWF to avoid a versions separation. The applicability in IFS should be considered.
5. Task 5 will be initiated by Barbara Fay (DWD) who will retire soon and will be followed by RHM.
6. The usual risks of radiation and convection schemes changes can affect the overall model performance at first stage.
7. The time evaluation for each task is approximation only.
8. The work on the tasks should be prioritized according to human resources and operational considerations.

References

1. Hogan, R. J. & Bozzo, A., 2018. A flexible and efficient radiation scheme for the ECMWF model. Journal of Advances in Modelling Earth Systems, 10.
2. Fu Q., 2007, A New Parameterization of an Asymmetry Factor of Cirrus Clouds for Climate Models, J. Atm. Sci. V. 64, 4140-4150
3. *Alapaty, K., J. A. Herwehe, T. L. Otte, C. G. Nolte, O. R. Bullock, M. S. Mallard, J. S. Kain, and J. Dudhia (2012), Introducing subgrid-scale cloud feedbacks to radiation for regional meteorological and climate modeling, Geophys. Res. Lett., 39, L24809, doi:10.1029/2012GL054031.*
4. Tanre, D., J.-F. Geleyn, and J. Slingo, 1984. First results of the introduction of an advanced aerosol-radiation interaction in the ECMWF low resolution global model. In Proc. of the Meetings of Experts on Aerosols and their Climatic Effects, Williamsburg, VA, pp. 133–177. WMO and IAMAP.
5. Tegen, I., P. Hoorig, M. Chin, I. Fung, D. Jacob, and J. Penner (1997), Contribution of different aerosol species to the global aerosol extinction optical thickness: Estimates from model results, J. Geophys. Res., 102, 23,895– 23,915.
6. Fan J., M. Ovtchinnikov, J.M. Comstock, S. A. McFarlane and A. Khain (2009), Ice formation in Arctic mixed-phase clouds: insights from a 3-D cloud resolving model with size-resolved aerosol and cloud microphysics. *J. Geoph. Res. D. (Atmospheres)*114(D04205):, doi:10.1029/2008JD010782

7. Khain A., T. V. Prabha, N. Benmoshe, G. Pandithurai, M. Ovchinnikov (2013), The mechanism of first raindrops formation in deep convective clouds, *Journal of Geophysical Research: Atmospheres* V. 118, Issue 16, 9123–9140, 27 August 2013.

8. Khain A.P. and COAUTHORS, 2015: “Representation of microphysical processes in cloud-resolving models: spectral (bin) microphysics vs. bulk parameterization” Reviews of Geophysics,

   http://onlinelibrary.wiley.com/doi/10.1002/2014RG000468/full

9. Ovchinnikov M., A. S. Ackerman, A. Avramov, A. Cheng, Jiwen Fan, A. M. Fridlind, S. Ghan1, J. Harrington, C. Hoose, A. Korolev, G. M. McFarquhar, H. Morrison, M. Paukert, M. Savre, Ben J. Shipway, M. D. Shupe, A. Solomon, and K. Sulia (2014), Inter-comparison of large-eddy simulations of Arctic mixed---phase clouds: importance of ice size distribution assumptions, *J. Adv. Mod. Earth. Systems* , 6, issue 1, 223-248.

10. J.-J. Morcrette,O. Boucher, L. Jones,D. Salmond,P. Bechtold,A. Beljaars, A. Benedetti, A. Bonet, J. W. Kaiser, M. Razinger, M. Schulz, S. Serrar, A. J. Simmons, M. Sofiev, M. Suttie, A. M. Tompkins, and A. Untch, Aerosol analysis and forecast in the European Centre for Medium-Range Weather Forecasts IntegratedForecast System: Forward modeling, Journal of Geophysical Research, V. 114, D06206, doi:10.1029/2008JD011235, 2009

11. A. Bozzo, S. Remy, A. Benedetti, J. Flemming, P. Bechtold, M.J. Rodwell and J.-J. Morcrette, Implementation of a CAMS-based aerosol climatology in the IFS. ECMWF 801 Technical Report, April 2017.

12. Chou M.D Suarez M.J, A Solar Radiation Parameterization for Atmospheric Studies, Technical Report Series on Global Modeling and Data Assimilation, NASA/TM-1999-10460, Vol. 15, 2002

13. Chubarova N., A. Smirnov, B.N. Holben, Aerosol properties in Moscow according to 10 years of AERONET measurements at the meteorological observatory of Moscow State University, Geog. Environ. Sustain. 4 (1) (2011) 19–32.

14. Oreopoulos, L., et al., The Continual Inter-comparison of Radiation Codes: Results from Phase I, J. Geophys. Res.,2012., 117, D06118, doi:10.1029/2011JD016821.

15. Tarasova T.A., Fomin B.A., The Use of New Parameterizations for Gaseous Absorption in the CLIRAD-SW Solar Radiation Code for Models, J Atmos Ocean Tech vol. 24 №6 June 2007,1157-1162.

16. Kinne, S., D. O’Donnel, P. Stier, S. Kloster, K. Zhang, H. Schmidt, S. Rast, M. Giorgetta, T. F. Eck, and B. Stevens (2013), MAC-v1: A new global aerosol climatology for climate studies, J. Adv. Model. Earth Syst., 5, 704–740, doi:10.1002/jame.20035.

17. Tarasova T.A., ChubarovaN.Ye. On the calculation of optical thickness of extended low and middle clouds using measurements of solar radiation in three solar spectrum ranges on the Earth's surface. Izvestiya- Atmospheric and Oceanic Physics, 30:253-257, 1994

18. Polyukhov A.A. Chubarova N.E. Rivin G.S., Shatunova M.V. The assessments of the accuracy of radiative calculations by the COSMO-Ru mesoscale prognostic model and the aerosol influence on the forecast of meteorological elements. INTERNATIONAL SYMPOSIUM "ATMOSPHERIC

RADIATION and DYNAMICS", St.Petersburg-Petrodvorets, June 23 - 26, 2015

19. Mueller R., C. Träger-Chatterjee, Brief Accuracy Assessment of Aerosol Climatologies for the Retrieval of Solar Surface Radiation, Atmosphere 2014, 5, 959-972; doi:10.3390/atmos5040959

20. Chubarova N., Aleksei Poliukhov, Marina Shatunova, Gdaliy Rivin, Ralf Becker, Stefan Kinne Clear-Sky Radiative And Temperature Effects Of Different Aerosol Climatologies In The Cosmo Model, 2018,GEOGRAPHY, ENVIRONMENT, SUSTAINABILITY, V 11, № 1, p. 74-84

21. Chubarova N., Khlestova J., Shatunova M., Platonov V., Rivin G., Görsdorf U., Becker R. Cloud characteristics and cloud radiative effects according to COSMO mesoscale model and measurements, 2018, Proc. SPIE 10833, 24th International Symposium on Atmospheric and Ocean Optics: Atmospheric Physics, V. 10833, c. 108331N-1-108331N-8

22. Poliukhov A.A., Chubarova H.E., Shatunova M.V., Rivin G.S., Tarasova T.A., Makshtas A.P., Muskatel H. Radiative effect of different aerosol types in clear sky conditions according to COSMO-Ru model, 2018,Proc. SPIE 10833, 24th International Symposium on Atmospheric and Ocean Optics: Atmospheric Physics, V. 10833.

23. Sakradzija, M., Seifert, A., and Dipankar, A. (2016), A stochastic scale-aware parameterization of shallow cumulus convection across the convective gray zone, J. Adv. Model. Earth Syst., 8, 786– 812, doi:10.1002/2016MS000634

24. Sakradzija, M., & Klocke, D. (2018). Physically constrained stochastic shallow convection in realistic kilometer-scale simulations. Journal of Advances in Modeling Earth Systems, 10, 2755– 2776. https://doi.org/10.1029/2018MS001358

25. Larson VE, Griffin BM. 2013. Analytic upscaling of a local microphysics scheme. Part I: Derivation.Q. J. R. Meteorol. Soc.139, 46–57. DOI:10.1002/qj.1967

26. Kogan, Y.L. and D.B. Mechem, 2014: A PDF-Based Microphysics Parameterization for Shallow Cumulus Clouds. J. Atmos. Sci., 71, 1070–1089, https://doi.org/10.1175/JAS-D-13-0193.1

27. Segal, Y. and Khain, A. (2006): Dependence of droplet concentration on aerosol conditions in different cloud types: Application to droplet concentration parameterization of aerosol conditions. Journal of Geophysical Research Atmospheres 111(D15).

28. Slingo, A., 1989: A GCM parameterization for the shortwave radiative properties of water clouds. J. Atmos. Sci., 46, 1419–1427.

29. Lindner, T. H., and J. Li, 2000: Parameterization of the optical properties for water clouds in the infrared. J. Clim., 13, 1797–1805.

30. Edwards, J. M., and A. Slingo, 1996: Studies with a flexible new radiation code: 1. Choosing a configuration for a large-scale model. Q. J. R. Meteorol. Soc., 122, 689–719.

31. Khain, P., R. Heiblum, U. Blahak, Y. Levi, H. Muskatel, E. Vadislavsky, O. Altaratz, I. Koren, G. Dagan, J. Shpund, and A. Khain, 2019: Parameterization of Vertical Profiles of Governing Microphysical Parameters of Shallow Cumulus Cloud Ensembles Using LES with Bin Microphysics. J. Atmos. Sci., 76, 533–560.

32. Grythe, H., Ström, J., Krejci, R., Quinn, P., & Stohl, A. (2014). A review of sea-spray aerosol source functions using a large global set of sea salt aerosol concentration measurements. Atmos. Chem. Phys., 14(3), 1277-1297.

33. Kok, J. F. (2011a). A scaling theory for the size distribution of emitted dust aerosols suggests climate models underestimate the size of the global dust cycle. P. Natl. Acad. Sci., 108(3), 1016-1021.

34. Kok, J. F. (2011b). Does the size distribution of mineral dust aerosols depend on the wind speed at emission? Atmos. Chem. Phys., 11(19), 10149-10156.

35. Kok, J. F., Mahowald, N. M., Fratini, G., Gillies, J. A., Ishizuka, M., Leys, J. F., & Zobeck, T. M. (2014). An improved dust emission model–Part 1: Model description and comparison against measurements. Atmos. Chem. and Phys., 14(23), 13023-13041.

36. Rieger, D., Steiner, A., Bachmann, V., Gasch, P., Förstner, J., Deetz, K., & Vogel, H. (2017). Impact of the 4 April 2014 Saharan dust outbreak on the photovoltaic power generation in Germany. Atmos. Chem. Phys., 17(21), 13391.

Task	**Contributing scientist(s)**	**FTE-years**	**FTE per person**	**Start**	**Deliverables**	**Date of delivery**	**Preceding tasks**
1.1	Ulrich Blahak (DWD) Harel Muskatel (IMS)	0.25	U -0.05 H-0.2	01.03.2020	Implementation of the new bulk parametrizations based on Fu in ecRAD	28.02.2021	-
1.2	Alon Shtivelman (IMS) Pavel Khain (IMS)	0.25	A-0.1 P-0.15	01.03.2020	Case studies and sensitivity analysis	28.02.2021	1.1
2.1	Ulrich Blahak (DWD) Harel Muskatel (IMS)	0.25	U -0.05 H-0.2	01.03.2020	Implementation of HS93 parametrization in the ecRAD framework	28.02.2021	-
2.2	Alon Shtivelman (IMS) Pavel Khain (IMS) Yoav Levi	0.3	P-0.15 A-0.1 Y-0.05	01.03.2020	Case studies and sensitivity analysis	28.02.2021	2.1
3.1	Harel Muskatel (IMS) Ulrich Blahak (DWD)	0.5	H-0.4 (0.2 per year) U -0.1 (2nd year)	01.03.2020	Implementation of SK method in ICON 1-mom scheme with different aerosols inputs	28.02.2022	-
3.2	Pavel Khain (IMS)	0.2	P-0.2	01.03.2021	Implementation of R_{eff} parametrization methods using the calculated prognostic cloud droplets number concentration	28.02.2022	-
3.3	Pavel Khain (IMS) Harel Muskatel (IMS)	0.35	P-0.1 H-0.1 A-0.1 Y-0.05	01.03.2021	Case studies and sensitivity analysis	28.02.2022	3.1-3.2

Task	Contributing scientist(s)	FTE - years	FTE per person	Start	Deliverables	Date of delivery	Preceding tasks
	Alon Shtivelman (IMS) Yoav Levi						
4.1	Harel Muskatel (IMS) Daniel Rieger (DWD)	0.1	H-0.05 D-0.05	01.03.2021	Enabling the download of all CAMS fields from MARS (mars4icon_smi package), Implementing the CAMS 4D fields in the iconremap interpolation tool.	28.02.2022	-
4.2	Harel Muskatel (IMS)	0.2	H-0.2	01.03.2021	Implementation of the prognostic CAMS aerosols in ecRAD	28.02.2022	-
4.3	Alon Shtivelman (IMS) Pavel Khain (IMS)	0.2	A-0.1 H-0.1	01.03.2021	Sensitivity analysis and case studies performed	28.02.2022	4.1-4.3
5.1	Poliukhov (RHM) Chubarova (RHM) Shatunova (RHM)	0.2	P-0.05 C-0.05 S-0.1	01.03.2020	Implementing the CAMS climatology fields as an external parameters file for ICON model	28.02.2021	-
5.2	Poliukhov (RHM) Chubarova (RHM) Shatunova (RHM) Khlestova (RHM)	0.35	P-0.1 C-0.1 S-0.1 K-0.05	01.03.2021	Sensitivity analysis and case studies performed	28.02.2022	5.1
6.1	Daniel Rieger (DWD)	0.2	D-0.2 (0.1/year)	01.03.2020	Mineral dust optical depth source function	28.02.2022	-
6.2	Daniel Rieger (DWD)	0.2	D-0.2 (0.1/year)	01.03.2020	Sea salt optical depth source function	28.02.2022	-
6.3	Daniel Rieger (DWD)	0.5	D-0.5 (0.25/year)	01.03.2020	Anthropogenic optical depth source function	28.02.2022	-
7.1	Poliukhov (RHM) Chubarova (RHM) Rivin (RHM) Khlestova (RHM)	0.3	P-0.15 C-0.05 R-0.05 K-0.05	01.03.2020	The implementation of Kinne MACv2 aerosol climatology in the ICON model	28.02.2021	-
7.2	Poliukhov (RHM) Chubarova (RHM) Rivin (RHM)	0.25	P-0.1 C-0.1 R-0.05	01.03.2021	The results of intercomparisons of different aerosol ICON simulations with the accurate off-line model simulations in clear sky conditions	28.02.2022	-
8.1	Poliukhov (RHM) Chubarova (RHM) Rivin (RHM)	0.2	P-0.05 C-0.05 R-0.05 K-0.05	01.03.2020	The results of intercomparisons of different aerosol ICON simulations with the accurate experimental	28.02.2021	-

Task	**Contributing scientist(s)**	**FTE-years**	**FTE per person**	**Start**	**Deliverables**	**Date of delivery**	**Preceding tasks**
	Khlestova (RHM)				measurements in clear sky conditions		
8.2	Khlestova (RHM) Chubarova (RHM) Shatunova (RHM) Rivin (RHM)	0.4	K-0.15 C-0.05 S-0.15 R-0.05	01.03.2021	The assessment of the absolute and relative deviations between the forecasted and observed meteorological parameters due to new cloud scheme and different aerosol inputs	28.02.2022	-
8.3	Khlestova (RHM) Chubarova (RHM) Shatunova (RHM) Rivin (RHM) Poliukhov (RHM)	0.5	K-0.1 C-0.1 S-0.15 R-0.05 P-0.1	01.03.2021	The results of intercomparison of different aerosol COSMO simulations with the 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	28.02.2022	
9.1	Pavel Khain (IMS)	0.2	P-0.2	01.03.2020	Testing the stochastic shallow convection parametrization	28.02.2021	-
9.3	Pavel Khain (IMS)	0.2	P-0.2	01.03.2020	Precipitation from the stochastic shallow convection parametrization	28.02.2021	-
10.1	Pavel Khain (IMS)	0.15	P-0.15	01.03.2021	Parameters sensitivity	28.02.2022	1-5
10.2	Pavel Khain (IMS)	0.15	P-0.15	01.03.2021	Tuning the cloud-radiation scheme	28.02.2022	1-5
L	Harel Muskatel (IMS)	0.2	H-0.2	01.03.2020	Project leadership	28.02.2022	
All		**6.6**		**01.03.2020**		**28.02.2022**	

Estimated resources (in FTE per year) needed COSMO-year:

	2020-2021	2021-2022
Ulrich Blahak	**0.1 FTEs**	**0.1 FTEs**
Daniel Rieger	**0.45 FTEs**	**0.5 FTEs**
Pavel Khain	**0.7 FTEs**	**0.7 FTEs**
Harel Muskatel	**0.7 FTEs**	**0.65 FTEs**
Alon Shtivelman	**0.2 FTEs**	**0.2 FTEs**
Yoav Levi	**0.05 FTEs**	**0.05 FTEs**
Poliukhov	**0.25 FTEs**	**0.3 FTEs**
Chubarova	**0.15 FTEs**	**0.35 FTEs**
Shatunova	**0.1 FTEs**	**0.4 FTEs**
Khlestova	**0.1 FTE**	**0.3 FTEs**
Rivin	**0.1 FTEs**	**0.15 FTEs**
Total:	**2.9 FTEs**	**3.7 FTE**