COSMO Priority Project Testing and Tuning of Revised Cloud Radiation Coupling ($T^2(RC)^2$): Project Plan

Version 11.0, 23.07.2015

Project duration: 09.2015 – 09.2017

Project leader: Harel Muskatel

Summary

This project is following the PT – Revised Cloud Radiation Coupling $(RC)^2$. The main goal is to improve the current cloud-radiation-coupling. In this project we intend to test the $(RC)^2$ results of the new optical properties of clouds. Also we will continue to explore the model sensitivities to several new tuning parameters and try to further reduce their number. The new radiation scheme will be tested under different weather conditions. Currently it is not yet planned to transfer the methods to the radiation scheme RRTM, because currently there are no resources within COSMO to implement RRTM from ICON to the common physics library. However, if this should change in the near future, we would take on the task of method transfer.

The second goal of this project deals with other physical aspects of the radiation scheme in order to implement the COSMO-Science-Plan 2015-2020 (CSP): aerosols and Sub-Grid Scale (SGS) clouds. Currently, the radiation scheme uses climatology data as the base for aerosols concentration. We shall examine the possibility of integration of the ECMWFMACC project (Monitoring Atmospheric Composition & Climate) prognostic aerosols fields to the COSMO radiation scheme. The SGS clouds parametrization scheme for radiation should also be reviewed and revised in light of the last years increase in resolution, the recent scientific progress in the field and in aid of a consistent overall description of clouds in the model.

The third goal is testing numerical aspects of the radiation code namely the temporal resolution optimization and the "Monte-Carlo Spectral Integration" (MCSI) as suggested in the CSP. We also will evaluate the possibility of transforming the radiation code (at least parts of it) into single precision.

In addition, experimental datasets in clear/cloudy sky conditions using the complex data of Moscow State University Meteorological Observatory (www.momsu.ru) will be used for testing both the radiation code (longwave and shortwave radiative components) and the application of two aerosol products; the MACC prognostic aerosol fields and a new aerosol climatology from Kinne et al. (2013). The results obtained with the above new cloud parameterization will be also verified against the experimental datasets. We also plan to apply accurate model simulations to verify the RT code used in COSMO. Testing the sensitivity of main prognostic meteorological characteristics to the changes in radiation fields and the assessment of the forecast quality to the changes made in radiation scheme with the different aerosol/cloud inputs will be also fulfilled.

Motivation

Radiation is the main source of earth's energy and is strongly coupled to other elements of NWP models especially the heating and cooling rates. On the other hand, precise line by line calculation of extinction of radiation in the atmosphere due to different scatterers and absorbers is computationally costly. Wise parametrizations of the cloud hydrometeors and aerosols optical properties and also a smart computational algorithm are key aspects of a fast and accurate operational radiation transfer model.

In the $(RC)^2$ - Revised Cloud Radiation CouplingPriority Task, re-computation of optical properties (optical thickness, single scattering albedo, asymmetry factor and delta-transmission function) of different hydrometeors in clouds in the COSMO model has been done using state of the art spectroscopic data (Fu 2007). These parameters are input to the radiation scheme and determine the model behaviour to a certain extent. Also, the aerosols were treated by the newer climatology of Tegen (Tegen et al. 1997) instead of the older Tanre-climatology (Tanre et al. 1984), the latter giving mostly a too high optical thickness. The new scheme changes the systematic behaviour of the current one: the cloud optical thickness of different cloud types is changed, not only cloud drops and cloud ice are input to radiation calculations, but also snow, graupel and rain (snow is most important), and in cloud-free situations there is less aerosol extinction now. Although the use of Tegen climatology already improved the situation for cloud-free situations, it is still a climatology which can obviously cause large biases in the estimates of radiation currents on a daily basis. The use of prognostic operational fields of a forecast model for aerosols as an input to the radiation scheme has some potential to improve COSMO forecasts. However, we are aware of possible drawbacks for extreme cases (e.g., cold front passage), where the aerosol fields of the aerosol forecast model might not be in phase with the weather conditions in the COSMO forecast.

As far as related to radiation, cloudiness (cloud-water and cloud-fraction of a model-grid-box) is currently derived from 3 contributions in the COSMO-model: grid scale cloud-water (according to grid-scale saturation adjustment) and 2 SGS contributions. One of them (based on a diagnostic relative-humidity-closure) is applied to that part of the grid box being not covered by shallow and deep convective clouds, and the other (employing a constant in-cloud value) is applied to the convective cloud-fraction, where the latter is estimated by our Tiedtke-type parameterization schemes for convection. According to the CSP, the over-all estimate of cloudiness has to be reviewed since the current parametrization seems to be too simplistic and in some cases not realistic. It possibly compensates for systematic biases related to the old Tanre-climatology, the old cloud optical properties and the missing snow category in radiation. In order to gain more accuracy as well as consistency, the local-saturation-adjustment procedure of the turbulence scheme should be examined for calculating overall cloudiness of that grid-box-fraction being not covered by convective clouds. For full consistency in this respect, the so far grid-scale saturation adjustment should be substituted by the overall cloudiness estimate (as demanded in the CSP).

The computational changes suggested above have an obvious motivation. Using single precision can save significant CPU time as was shown in the POMPA PP. So far we have been careful with moving towards single precision in the radiation scheme due to accuracy reasons but the idea should be tested and considered. Here we can build on previous experiences of the POMPA project. Refining the temporal resolution could save computational costs in some cases and on the other hand define a better resolution in rapidly changed environments.

The MCSI method is also a possible way of reducing computational effort by a wise randomization of spectral interval calculations while preserving accuracy in a statistical sense.

Preliminary results (Polyukhov et al., 2015) show that even the Tegen aerosol climatology (1997) provide too high aerosol loading. At the same time the sensitivity studies revealed high impact of aerosol on temperature near surface. The new aerosol dataset proposed by Kinne et al (2013) is considered to better describe real aerosol loading (Mueller and Träger-Chatterjee, 2014). Verification of both the computationally cheap new Kinne et al. (2013) climatology as well as the prognostic MACC aerosol against the data of Moscow State University Meteorological Observatory, which 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), provides a reliable dataset for testing in different 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 (aerosol fields from of the ECMWF-MACC project and a new aerosol climatology from Kinne et al. (2013). We also propose to test the COSMO shortwave code with different aerosol loading against other accurate model RT codes, which have participated in model inter-comparisons (Oreopoulos et al., 2013).

For cloudy conditions the same experimental base can be used for checking the new cloud algorithm in the (RC)2 scheme. This is possible, for example, due to the existing algorithm of Tarasova and Chubarova (1994) for evaluation of cloud optical thickness from shortwave radiometer data in overcast cloudy conditions, or an updated variant of this algorithm. The sensitivity of the most important meteorological forecast quantities to the new aerosol/cloud inputs, applied in the radiative scheme, is planned to be estimated as well as to assess the forecast quality change due to the changes made in the radiation scheme with different aerosol/cloud inputs.

Actions proposed

1. Testing and tuning of the new cloud-radiation scheme performance (Task 1)
2. Analysis/Revision of SGS cloudiness in the radiationscheme(Task 2)
3. Testing the use of actual MACC aerosol fields instead of climatology in the radiationscheme (Task 3)
4. Adapting switchable single/double precision to the radiation scheme (Task 4)
5. Implementation and testing of the MCSI method (Task 5)
6. Testing the radiation code (longwave and shortwave components) and the proposed prognostic MACC aerosol fields together with a new aerosol

climatology from Kinne et al. (2013) against experimental datasets for clear/cloudy sky conditions using the data of Moscow State University Meteorological Observatory (Task 6)

Description of individual tasks

Task L: Project leadership

Estimated resources: 0.1 FTE per year

Task 1: Testing and tuning of the new cloud-radiation scheme performance

As part of the recent PT $(RC)^2$ re-computation of the optical properties (optical thickness, single scattering albedo, asymmetry factor and delta-transmission function) of different hydrometeors in clouds in the COSMO model has been performed using state of the art spectroscopic data (Fu 2007). Further, an option was added to derive the cloud number density (important for eff. radius of cloud drops) from the Tegen aerosol climatology instead of using a constant value. These changes were implemented in a revised version of the radiation scheme (not operational yet) and have to be tested in different weather situations. Also, several other physical processes have been added which occur in nature but up to now were absent in the model. These additions yielded tens of new parameters, having clear physical meaning. The model is highly sensitive to some of these parameters and less to others. As part of PT $(RC)^2$ sensitivities to different parameters were tested using the idealized COSMO framework (developed by Ulrich Blahak) for typical clouds, namely cirrus, low stratus, mixed phase stratus, fair weather cumulus and cumulonimbus. As a result, the most sensitive parameters have been identified.

Therefore we propose the following subtasks:

1.1 Case studies for different weather situations

We propose to test these sensitivities in different weather situations, using the full COSMO model. These weather situations will be chosen, so that various cloudiness conditions could be tested. Based on these case studies, “expert tuning” of both sensitive and insensitive parameters will be performed. It should be mentioned, that as much as possible of the uncertain parameters should be determined by “expert-tuning” in the sense of “component-testing”, in contrast to "system-testing" used in the CALMO method which is much more computationally expensive.
As a result, a final set of sensitive parameters will be defined and imported to the COSMO namelist, while the others will be predefined within the code.

1.2 An automatic parameters tuning using the PP CALMO methods

This method defines a „Meta-Model” which allows estimating the simulated atmospheric variables of interest for specific input of model parameters, without conducting full model simulations. Neelin et al. (2010) proposed to define the meta-model as a simple quadratic regression in n-dimensional model parameters space. Interactions of parameter perturbations are approximated by a nonlinear term for each parameter pair. Perturbations of more than two parameters are therefore approximated with nonlinear terms of all possible pairs. Verification of the Meta-Model against observations (2m-temperature, brightness temperature, etc.) allows for determining the optimal model parameters (using a defined cost function). Up to now, within the CALMO project (2014-2015), 3 parameters from the COSMO turbulence scheme were successfully tuned. Here we propose to use a similar method to automatically tune parameters of the radiation scheme, which turned out to be sensitive in Task 1.1 above.We should bear in mind that some other uncertain model parameters, in particular related to surface process (such as,e.g., the 'minimal stomata-resistance' of plant leaves or 'surface-albedo'-parameters) are somehow tuned dependent on the radiation supply form above. As this radiation supply is dependent on the updated formulation of radiation coupling - and in particular also on the modifications by the new Tegen-climatology for aerosols, such mentioned parameters of surface might need to be adapted as well.

The new radiation related code will have to be switched to GPU version that can be run on CSCS which has GPU architecture.

Deliverables:

(09.2016, 0.25 FTE, Pavel 0.1, Harel 0.05, Uli 0.05) Final set of tuning parameters available (also in the official COSMO version, if needed by others)

(09.2016, 0.25 FTE, Pavel 0.1, Harel 0.05, Uli 0.05) Case studies performed

(09.2017, 0.1 FTE, Pavel 0.1, Xavier Lapillonne) Re-write the new radiation related portions of the code to be adapted to GPU architecture.

(09.2017, 0.1 FTE, Pavel 0.1, Oliver 0.05) Automatic parameter tuning performed, "best" settings available, probably different for different climatic zones.

P(avel) (0.4 FTE), H(arel) (0.1 FTE), U(li) (0.1 FTE), X(avier) (0.1), O(liver) (0.05)

Estimated resources: 0.75 FTE

Status: Not yet done.

Task 2: Analysis/Revision of SGS cloudiness in radiation

This task is divided into two parts. The first one (2.1) is dealing with a more sophisticated estimate of overall cloudiness and thus is strongly related to the description of SGS variability by turbulence and convection. The second one (2.2) concentrates on the proper representation of SGC variability in the formulation of effective optical properties by use of the information from 2.1.

2.1 As stated in the Motivation section, we aim to revise the overall estimation of cloudiness, possibly by a proper combination of information from the turbulence scheme (local saturation adjustment) and the convection scheme. First of all, we can investigate the already implemented option to substitute the relative-humidity contribution by the local saturation adjustment applied in the turbulence scheme (statistical cloud scheme). In order to better include the ice phase, we further aim to re-introduce a mixed water-ice phase extension into the turbulence scheme (as it is present in the new common COSMO/ICON-module TURBDIFF) based on an implementation into an early test-version by Matthias Raschendorfer. In this respect however, we have to consider the problem that cloud-ice can't completely be described by a saturation equilibrium. Rather, we need to dynamically adapt the ice/water-ratio in accordance with the results of the scheme for cloud microphysics. In this connection, we also want to consider a special cloud diagnostics that has been implemented in ICON by Martin Köhler. This scheme, however, is also based on relative humidity without taking into account statistical properties from turbulence or convection.

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2.2 In order to consider the effect of SGS variability in the derivation of optical properties from the cloud-information provided by Task 2.1, we want to derive a parameterization of the effective radius of SGS clouds (in terms of grid-scale variables and statistical information from turbulence and convection) using the facility of System-Atmospheric-Modeling with spectral bin microphysics (SAM-SBM).

Recently two very accurate microphysical cloud models were developed. The models are: 2D Hebrew University cloud model (HUCM) and System Atmospheric Modeling with spectral bin microphysics (SAM-SBM). Both models use the so called spectral (bin) microphysics for description of microphysical processes. It means that the models solve equations for size distribution functions of different hydrometeor types: water drops, ice crystals, aggregates (snow), graupel and hail. To describe cloud aerosol interaction, a special size distribution function for aerosols is used. Each size distribution is defined on mass grids containing several tens of bins. SAM-SBM uses the microphysical package developed and used in HUCM. Different aerosol concentrations can be specified at the beginning of the simulations.

The models were successively used for simulation of different types of clouds: warm stratocumulus, mixed-phase stratocumulus (Fan et al, 2009, Ovchinnikov, 2014), convective clouds and deep-mixed-phase convective clouds (Khain et al, 2013; see review, Khain et al, 2015). In addition to size distributions, the output of the models includes all major microphysical parameters which characterize the distributions: mass and number concentrations, mean and effective radii, radar reflectivity, etc.

The characteristic resolution used in these simulations is several tens to hundred meters. As the clouds simulated by the models are SGS clouds for COSMO, we plan to perform several simulations and calculate fields of effective radius and other parameters needed for the COSMO radiation scheme. (The following would be a little too ambitious and too unsure for this project plan)

Deliverables:

(09.2016, 0.15 FTE, Pavel 0.05, Harel 0.05, Uli 0.05) Analysis and understanding of current SGSC parameterization

(09.2016, 0.2FTE, Pavel 0.05, Harel 0.05, Matthias 0.1) Testing and adaption of the alternative SGSC parameterization in the turbulence scheme

(09.2017, 0.3 FTE, Pavel 0.2, Harel 0.05, Uli 0.05) HUCM idealized 2D cases for the simpler stratiform cloud types mentioned above and analysis of their Reff under different aerosol conditions

(09.2017, 0.3 FTE, Pavel 0.2, Harel 0.05, Uli 0.05) 3D SAM simulations of the more convective cloud types mentioned above and analysis of Reff, also for different aerosol conditions

FTEs altogether: P 0.5, H 0.2, U 0.15, M 0.1

Estimated resources: 0.95 FTE

Status: Not yet done.

Task 3: New aerosols fields from MACC (ECMWF)

The spatial distribution of aerosols has a large impact on hitting/cooling rates and on radiation fluxes. Currently aerosols data are treated climatologically with two optional schemes: the Tanre and the Tegen Climatology. Both are non-prognostic and give only a statistical hint rather than actual forecast for each type of aerosol that is part of the radiation model. Until the operational use of COSMO-ARTon a daily basis we will examine the possibility of incorporating the MACC aerosols fields (Morcrette et al. 2009)). This model includes prognostic variables for the mass of sea salt, dust, organic matter, black carbon and sulfate aerosols, interactive with both the dynamics and the physics of the IFS model. Implementing these fields into the radiation model of COSMO has to be tested under real circumstances and compared with the current method. Possible drawbacks, e.g., related to “IFS weather being out of phase with COSMO weather in extremely clean or polluted cases”, have to be investigated. It is in any case expected to significantly affect the radiation fluxes in some cases and may cause at first a deterioration of COSMO scores. A re-tuning of some other model parameters might be probably unavoidable.

Deliverables:

(09.2016, 0.2 FTE, Harel 0.2) Adaptation of MACC aerosols fields into COSMO framework (units, spatial interpolation , …), usable in test versions of INT2LM and COSMO.

(09.2017, 0.3 FTE, Harel 0.3) Case studies, documentation of effects

FTEs altogether: H 0.5

Estimated resources: 0.5 FTE

Status: Not yet done.

Task 4: Adapting switchable single/double precision to radiation scheme

Reducing arithmetic precision in a numerical weather prediction model, and thus reducing the number of bytes required to store a floating point number, can be advantageous for an application such as COSMO both in terms of runtime and memory consumption. But, since the COSMO model has been written and applied only using double precision (DP) floating point numbers, reducing arithmetic precision requires careful consideration. Results indicate that the newly developed version of model, running in single precision (SP) exhibits the same forecast skill as the reference version both in SP and DP mode. In SP, the runtime drops to ~60% and memory consumption is reduced considerably, as compared to the DP mode. (S. Rudisuhli et al., COSMO Newsletter No. 14).

As a part of PP POMPA / PT 7, most parts of COSMO model were rewritten to enable switchable single/double precision. The only part of the code where substantial modifications are necessary to run it in SP is the radiation scheme, which in its current form has to run partly in DP regardless of the model's working precision (WP). A detailed code analysis has been performed by PP POMPA in MeteoSwiss. They have not proven the algorithms in radiation code to strictly require DP but rather have simply not succeeded in finding the critical modifications required to enable SP also for the radiation code. Based on this work, we are hereby to suggest further investigation of the earlier identified parts of the radiation scheme, and subsequent code modification so to adapt the radiation scheme to run in switchable SP/DP mode. This investigation has to incorporate the code changes related to the revised cloud radiation coupling.

Deliverables:

(09.2016, 0.2 FTE, Alon 0.2, Oli 0.05) Experiments for comparison of quality and efficiency of SP and DP radiation. Test code for single precision radiation available.

(09.2017, 0.2 FTE, Alon 0.2, Oli 0.05) Experiments evaluated and recommendations for official COSMO code

FTEs altogether: Alon 0.4, Oliver Fuhrer 0.1

Estimated resources: 0.5 FTE

Status: Not yet done.

Task 5: Implementation and testing of the MCSI method

5.1 Temporal resolution of the radiation calculation optimization

Due to the high computational cost of radiative transfer calculation scheme, it is only called every 1hr/15min in COSMO-7km and COSMO-2.8km, respectively. This, of course, has accuracy cost i.e. as a result of clouds/aerosols movement in these time intervals, and may cause temporal errors on a spatial resolution of the radiation fluxes. On the other hand, calling the radiation scheme on every model time step is not reasonable in terms of CPU run time.In this sub-task we will investigate and document the impact of the coarse time step under different weather situations.

5.2 The MCSI method

One of the approaches suggested to reduce numerical effort in radiation transfer models is the Monte Carlo Spectral Integration (MCSI) (Pincus and Stevens 2009). In this method bias free sampling of the spectral bands are done instead of full spectral integration over the whole spectrum. The errors introduces by the method are said to be almost diminished due to fact that the sampling radiative hitting rates is done in a space orthogonal to the phase space of the flow (Pincus and Stevens 2009). In this PP we shall test the method in COSMO framework and try to evaluate its accuracy compared with the full 8-band calculation and to compare CPU time costs of the two methods. If the accuracy of this state-of-the-art sampling method will be reasonable, the temporal/spatial resolution may be accordingly increased.

Deliverables:

(09.2016, 0.1 FTE, Alon 0.1) Experiments conducted and effects documented of temporal resolution of radiation scheme
(09.2016, 0.3 FTE, Pavel 0.1, Harel 0.2, Uli 0.1) Implementation MCSI method in test version of COSMO

(09.2017, 0.3 FTE, Pavel 0.1, Harel 0.2, Uli 0.1) Case studies and documentation of effects

FTEs altogether: U 0.2, P 0.2, H 0.4, A 0.1

Estimated resources: 0.9 FTE

Status: Not yet done.

Task 6: Testing the radiation code against experimental datasets

Subtask 6.1. The verification of the output results (aerosol, radiation, main meteorological parameters) after application of the Kinne (MAC-v1) climatology and MACC aerosol fields from the ECMWFMACC project in clear sky conditions against 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@Zonnen net radiometer CNR-4 (upward and downward long-wave, shortwave fluxes, surface albedo), standard meteorological observations (temperature, ground water vapor pressure, relative humidity), satellite retrievals (total ozone). The period for the comparisons will cover the previous years since 2012 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.

Dr. Stefan Kinne (the main author of the Mac-v1 aerosol climatology) is ready to prepare the aerosol input parameters for the COSMO radiation code (Ritter and Geleyn, 1992).

For clear sky conditions the accurate comparison of COSMO radiative simulations will be made in the off-line regime for the same statistics with the benchmark Monte-Carlo simulations (Rublev et al., 2002) and modified CLIRAD_SW code (Chou et al., 2002; Tarasova and Fomin, 2007).

Subtask 6.2. For cloudy conditions the same experimental testbed at the Meteorological Observatory of Moscow State University (MSU) will be used for checking the new cloud algorithm in the (RC)2 scheme. We plan for this purpose to use direct CNR-4 measurements and, in addition, to apply the algorithm for the evaluation of cloud optical thickness from shortwave radiometer data in overcast cloudy conditions (*Tarasova and Chubarova, 1994*) or its updated variant. The comparisons will be fulfilled for overcast conditions. The number of cases will be about 30-50 for different surface albedo conditions since 2012.

Subtask 6.3. To evaluate the sensitivity of the main forecasted meteorological parameters (air temperature, for example, and some others) to aerosol/cloud characteristics applied in the radiative scheme, and to assess the changes in the absolute and relative deviations between real measurements and forecasted values due to the changes made in the radiation scheme and under different aerosol inputs.

Impact on COSMO code: Apart of the obvious impact of the implementation of the new Kinne climatology in the code, the CALMO procedure (task 1.2) is verifying the Meta-model against observations. It is natural to define the "Cost function" against the measurements from the data set of MSU that is now available for us. Another probable outcome could be the choosing the most favourable aerosol scheme to be the COSMO default scheme.

Deliverables:

1. (09.2016, Shatunova – 0.1 FTE, Poliukhov – 0.1) The implementation of Kinne MAC-v1 aerosol climatology in the model
2. (09.2016, Poliukhov – 0.05 FTE, Chubarova – 0.1 FTE, Shatunova – 0.05 FTE, Rivin – 0.05 FTE) The results of intercomparisons of different aerosol COSMO simulations with the accurate experimental measurements in clear sky conditions
3. (09.2016, Poliukhov – 0.05 FTE, Chubarova – 0.1 FTE, Shatunova – 0.05 FTE, Rivin – 0.05 FTE) The results of intercomparisons of different aerosol COSMO simulations with the accurate off-line model simulations in clear sky conditions
4. (09.2017, Poliukhov – 0.05 FTE, Chubarova – 0.1 FTE, Shatunova – 0.05 FTE, Rivin – 0.05 FTE) The results of intercomparison of different aerosol COSMO simulations with the accurate experimental measurements in cloudy conditions
5. (09.2017, Poliukhov – 0.05 FTE, Chubarova – 0.05 FTE, Shatunova – 0.05 FTE, Rivin – 0.05 FTE) The assessment of the accuracy of implementation of new aerosol climatology to radiation fields and several meteorological parameters
6. (09.2017, Poliukhov – 0.05 FTE, Chubarova – 0.1 FTE, Shatunova – 0.05 FTE, Rivin – 0.05 FTE) The assessment of the absolute and relative deviations between the forecasted and observed meteorological parameters due to new cloud scheme and different aerosol inputs

FTEs altogether: Poliukhov – 0.35 FTE, Chubarova – 0.45 FTE, Shatunova – 0.35 FTE, Rivin – 0.25 FTE

Estimated resources: 1.4 FTE

Status: Not yet done.

Links to other projects or work packages

1. PP CALMO for an automatic tuning exercise using the most sensitive new radiation tuning parameters. Pavel Khain is member of both projects, so this will come more or less naturally.Task 1.2 will be performed using CALMO methodology which requires significant computing resources not available in the IMS. It should be mentioned that PP CALMO is not yet finished,hence we could not be sure that it would work as desired. Howevercomputing resources from other centerslike CSCS or DWD is needed. The code change to GPU version will need some technical support from Oliver Fuhrer from (MCH).

Risks

1. Allocation of computer resources for automatic tuning exercise at CSC.
2. Other than that, the usual risks of scientific developments that planned developments and tasks do not work out as originally anticipated.

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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) Pavel Khain (IMS) Harel Muskatel (IMS)	0.4	U -0.1 P-0.2 H-0.1	01.09.2015	Final set of tuning parameters Case studies performed	31.08.2016	-
1.2	Xavier Lapillonne (MCH) Pavel Khain (IMS) Oliver Fuhrer (MCH)	0.35	X-0.1 P-0.2 O-0.05	01.09.2016	Re-write the new radiation related portions of the code adapted to GPU architecture. Automatic parameter tuning performed (CALMO method)	31.08.2017	1.1
2.1	Ulrich Blahak (DWD) Matthias Raschendorfer (DWD) Pavel Khain (IMS) Harel Muskatel (IMS)	0.35	U -0.05 M-0.1 P-0.1 H-0.1	01.09.2015	Analysis and understanding of current SGSC parameterization Testing and adaption of the alternative SGSC parameterization in the turbulence scheme	31.08.2016	-
2.2	Ulrich Blahak (DWD) Pavel Khain (IMS) Harel Muskatel (IMS)	0.6	U -0.1 P-0.4 H-0.1	01.9.2016	HUCM idealized 2D cases for the simpler stratiform cloud types mentioned above and analysis of their R_eff under different aerosol conditions 3D SAM simulations of the more convective cloud types mentioned above and analysis of Reff, also for different aerosol conditions	31.08.2017	2.1
3	Harel Muskatel (IMS)	0.5	H-0.5 (0.2 1st yr., 0.3 2nd yr.)	01.09.2015	Adaptation of MACC aerosols fields into COSMO framework (units, spatial interpolation , …) Case studies, documentation of effects	31.08.2017	-
4	Alon Shtivelman	0.5	A-0.4 (0.2 per	01.09.2015	Experiments for comparison of quality and efficiency of SP and	31.08.2017	-

Task	**Contributing scientist(s)**	**FTE-years**	**FTE per person**	**Start**	**Deliverables**	**Date of delivery**	**Preceding tasks**
	(IMS) Oliver Fuhrer (MCH)		year) O-0.1 (0.05 per year)		DP radiation Experiments evaluated and recommendations for COSMO code		
5.1	Alon Shtivelman (IMS)	0.2	A-0.2	01.09.2015	Experiments conducted and effects documented of temporal resolution of radiation scheme	31.08.2016	
5.2	Ulrich Blahak (DWD) Pavel Khain (IMS) Harel Muskatel (IMS)	0.8	U -0.2 P-0.2 H-0.4	01.09.2015	Implementation and testing of the MCSI method Case studies and documentation of effects	31.08.2017	-
6.1	Poliukhov (RHM) Chubarova (RHM) Shatunova (RHM) Rivin (RHM)	0.7	P-0.2 C-0.2 S-0.2 R-0.1	01.09.2015	Implementation of Kinne MAC-v1 aerosol climatology in the model Results of intercomparisons of different aerosol COSMO simulations with the accurate experimental measurements in clear sky conditions Results of intercomparisons of different aerosol COSMO simulations with the accurate off-line model simulations in clear sky conditions	31.08.2016	
6.2	Poliukhov (RHM) Chubarova (RHM) Shatunova (RHM) Rivin (RHM)	0.45	P-0.1 C-0.15 S-0.1 R-0.1	01.09.2016	Results of intercomparison of different aerosol COSMO simulations with the accurate experimental measurements in cloudy conditions Assessment of the accuracy of implementation of new aerosol climatology to radiation fields and several meteorological parameters	31.08.2017	
6.3	Poliukhov (RHM) Chubarova (RHM) Shatunova (RHM) Rivin (RHM)	0.25	P-0.05 C-0.1 S-0.05 R-0.05	01.9.2016	The assessment of the absolute and relative deviations between the forecasted and observed meteorological parameters due to new cloud scheme and different aerosol inputs	31.08.2017	
L	Harel Muskatel (IMS)	0.2	H-0.2	01.09.2015	Project leadership	31.08.2017	
All		**5.3**		**01.09.2015**		**31.08.2017**	

Estimated resources (in FTE per year) needed for COSMO-year 2015-2016:

Ulrich Blahak 0.25 FTEs

Matthias Raschendorfer 0.1 FTEs

Pavel Khain 0.4 FTEs

Harel Muskatel 0.7 FTEs

Alon Shtivelman 0.4 FTEs

Oliver Fuhrer 0.05 FTEs

Poliukhov 0.2 FTEs

Chubarova 0.2 FTEs

Shatunova 0.2 FTEs

Rivin 0.1 FTEs

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Total: 2.6 FTEs

Estimated resources (in FTE per year) needed for COSMO-year 2016-2017:

Ulrich Blahak 0.2 FTEs

Pavel Khain 0.7 FTEs

Harel Muskatel 0.7 FTEs

Alon Shtivelman 0.2 FTEs

Oliver Fuhrer 0.1 FTEs

Xavier Lapillonne 0.1 FTEs

Poliukhov 0.15 FTEs

Chubarova 0.25 FTEs

Shatunova 0.15 FTEs

Rivin 0.15 FTEs

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Total: 2.7 FTEs