Working Area Physics

Work Plan

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Period:	2021	
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Main subjects are still listed as in previous LACE physics plans, few related to Surface are added to be in line with ALADIN/HIRLAM/LACE Rolling plan 2021. Two overview tables with different organization but with same content are prepared under "Summary of resources". This plan reflects the actions for 20201

1 Introduction and background

The focus of the research and developing activities inside LACE is to achieve a scale-independent ALARO physics package which allows us to produce operational forecast at the resolution between 10 and 1 km mesh-size. The developments of physics schemes for high resolution gathered into ALARO-1 have been ongoing for more than 9 years. Most of individual schemes have reached the step of the individual tuning and validation; the tuning and further validation of the whole model where these modules interact together is going on.

The operational applications in LACE countries use:

- A baseline version of the ALARO-0 (available in December 2012, still used),

- the first version ALARO-1vA (available in December 2014)

- and also the newest second version ALARO-1vB (available February 2017).

Benefits of the high resolution with the ALARO-1 version are already seen.

This plan is reflected in the ALADIN/HIRLAM/LACE Work Plan for 2021, majority of tasks are under Work Packages PH3 (Development of ALARO physics), some in PH1 (Developments of AROME (and ARPEGE) physics), aim is to contribute to work inside PH4 (Common 1D MUSC framework for parametrization validation), PH5 (Model output post-processing parameters), PH6 (Study the cloud/aerosol/radiation (CAR) interaction), PH7 (Develop approaches for 3D physics), PH8 (Machine learning), PH9 (Consistency and convergence of the CSC physics), PH10 (Stochastic parametrisations) and HR1 ((Sub)-km configurations and turbulence R&D activity). There are also other Working packages under "Surface analysis and modelling" with contribution from RC LACE countries, SU3 (Validation of existing SURFEX model options for NWP) and SU6 (Coupling with sea surface/ocean) now included in this plan.

Due to restrictions in work and travel related to the Covid19 pandemic, many research stays have been postponed, colleagues were working from home and had reduced possibilities, therefore many research stays and subjects got postponed for 2021.

2 Goals

The highest priority is to optimize the performance of the LAM for resolutions in the 1 to 5 km range. Quality of simulations can be improved with better representation of clouds, as they are treated by a combination of different schemes (input to radiation, turbulence). With including of the refinements of the parametrization of the convective drafts it is expected to achieve seamless solutions across a wide range of horizontal resolutions, including the grey zone of moist deep convection, down to 1km.

Research will continue to enhance the description of physical processes also at sub-km resolutions (study of turbulence at grey zone, two-moment microphysics scheme). Experiments in very fine resolution (with ALARO and AROME) will indicate the problems which should be tackled. Additionally enhanced description of atmosphere-surface link available in SURFEX should be implemented. Better description of the (stable) boundary layer behaviour, low cloudiness, daily cycle of precipitation and convection under unstable circumstances are among the most desired improvements.

3 Main R&D activities

In 2021 we plan to continue the work on already ongoing topics. Main research activity in the year 2021 is the improvement of the description of cloudiness in various processes and the usage of SURFEX within ALARO-1. Validation of TOUCANS will continue. The first operational suite with ALARO-1vB at 2.3 km horizontal

resolution is implemented in Czech Republic, followed by Slovakia and Slovenia. The ALARO-1vB version is recommended for the operational use at various model resolutions. Additional effort will be invested to prepare new model output products which will suite to end-users.

Several Actions from this research plan should be handled by the new Diagnostics and verification Area leader from the beginning of 2021!

Action/Subject: **Turbulence scheme TOUCANS**

Description and objectives:

The turbulence scheme TOUCANS is integrated into ALARO-1 version. This scheme has many modern options for computation of turbulent fluxes of momentum, heat, water vapour and cloud condensed water. It includes also the description of shallow convection (non-precipitating, available in the latest version ALARO-1vB). Further validation is still needed to profit from many available options and to update the selected set-up used the operational applications (some options remained the same as in ALARO-0).

Research and development continue on mixing length computation, there are possible improvements in the shallow convection closure. Other tasks related to this subject include the verification of wind forecast quality and the improvement wind gust diagnostics.

Actions in 2021:
- finish and validate check and examine coding of some parts of TOUCANS (still in TOMs part, after code reorganization);
- study and test mixing length computation;
- include TOUCANS into DDH

Proposed contributors, Estimated efforts: P. Smerkol (Si), M. Hrastinski (Hr), J. Masek, R. Brozkova (Cz), 7 months (1.5+0.5 month LACE stays)

Planned timeframe: whole year

Planned deliverable: code modification, documentation updates

Action/Subject: Radiation scheme

Description and objectives:

Radiation scheme ACRANEB2 is integrated into ALARO-1 versions. Climatological aerosol optical properties can be replaced with those (daily) provided by Copernicus Atmosphere Monitoring Service (CAMS MACC products). Improvements in the cloud-radiation interaction are planed by taking into account better information on cloud cover (see under “Cloud scheme”) and (in future) by getting microphysical cloud condensates into radiation scheme.

Parametrization of an impact of cloudiness on broadband surface albedo, which is an important issue for the schemes using single SW interval, can be prepared.

Adaptations to improve also climate simulations can be studied. First step is more efficient computation of clear sky fluxes.

Actions in 2021:
- code, validate and phase efficient calculation of clear sky fluxes in ACRANEB2
- preparation of single precision version of externalized ACRANEB2
- *parameterization of an impact of cloudiness on broadband surface albedo (suitable/waiting for a newcomer)*

Proposed contributors, Estimated efforts: J. Mašek (Cz) 0.25 month

Planned timeframe: whole year

Planned deliverable: code, report

Sub-Action/Subject: Externalization of aerosol IOPs (Inherent Optical Properties) in ACRANEB2.

Description and objectives:

Currently, ACRANEB2 scheme works with 6 aerosol types with predefined optical properties (extinction coefficient, single scattering albedo and asymmetry factor), hardcoded inside ACRANEB2. The only aerosol input is optical depth for each aerosol type and model layer. It comes from monthly climatology that contains total optical depth (integrated from the top of the atmosphere to the surface), which is vertically distributed assuming aerosol concentration decaying exponentially with height, each aerosol type having its own characteristic height.

The goal of the stay would be to adapt ACRANEB2 code so that it works not only with external aerosol loads (optical depths), but also with externally specified optical properties of aerosol mixture. It means there will be just one aerosol type (not 6), but with varying optical properties depending on near real time concentrations and actual humidity. Stay will not address preprocessing/dataflow of CAMS aerosols, here we rely on HIRLAM colleagues to transfer it from h-codes to t-codes.

Important part of the exercise will be to create a new subroutine for converting old (static) aerosol optical properties into new (single type) description, so that the new scheme is able to reproduce results with old climatological aerosols. Work should not be very difficult, although there will be some issues to solve.

Actions in 2021:
- code, validate and phase the adapted code,

Proposed contributors, Estimated efforts: J. Mašek (Cz) 1.75 month, *P.Sekula (Pl) 2 months (1 month stay)*

Planned timeframe: whole year

Planned deliverable: code, report

Action/Subject: Cloud scheme

Description and objectives:

The objective is unification of the cloud-cover concept within ALARO-1.

Initially, it was decided not to aim at a single computation of cloudiness, like for instance in Tompkins (2002), but go for an alternative approach, to build bilateral correspondences and/or combinations for all cases where two parametrisations interact at the level of the cloud-cover definition. For example, in precipitation process combination of stratiform and deep convective cloudiness is used.

An issue is the harmonization of radiative cloud and condensates with the microphysical cloud fraction and prognostic condensates. Presently, the radiative condensates are re-estimated, the 'stratiform' part (contrary to the cloud scheme) does not include phase and mesh size dependencies, the convective condensates are re-estimated from the 'protected' historic convective cloud fraction.

At short term, cloud diagnostic in radiation should be re-tuned, in the spirit to reduce the difference with the thermodynamic adjustment. Relatively small upgrades with respect to current ALARO-1 version are needed. This transversal change is touching many feed-back loops, hence its practical consequences is quite unpredictable.

Recent case studies of winter-type stratocumulus (clouds are not kept) have shown a tendency of the model to remove the sharp gradient at the inversion top. It does not seem to be a priori a problem of the cloud scheme, e.g. when data assimilation restores the gradient, we get clouds. Therefore a more in depth analysis of the processes involved is needed.

Action in 2021:
- analysis of the process involved in dissipation of low clouds in winter situations
- unify the treatment of stratiform cloudiness in radiation and thermodynamic adjustment (modification and testing)
- further steps will be defined according to the outcomes

Proposed contributors, Estimated efforts: R. Brožková (Cz), J. Mašek (Cz), 4 person months

Planned timeframe: whole year

Planned deliverable: code modification, testing and validation

Action/Subject: Microphysics

Description and objectives:

Current microphysics schemes in AROME are ICE3 and ICE4 (prognostic hail included but not in operational use). Evaluation LIMA scheme is ongoing in AROME. LIMA is a two-moment microphysics scheme, which treats the number concentration of cloud condensation nuclei prognostically, and thus permits a physically more realistic treatment of aerosol-cloud interactions. Scheme was developed within Meso-NH, research version is implemented in AROME.

The implementation of prognostic graupel was phased into ALADIN code cy43t2 and cy46t1 by Bogdan Bochenek , technical and scientific validation should continue and some tuning inside microphysics is expected.

Action in 2021:
- sensibility tests of the LIMA scheme in AROME
- finish the phasing to the most recent cycle and validation of prognostic graupel computation in ALARO-1

Proposed contributors, Estimated efforts: B.Bochenek (Pl), 3 month LACE stay, R Brozkova (Cz) 2 months

Planned timeframe: whole year

Planned deliverable: testing and validation, report

Action/Subject: **Operational applications: from ALARO-0 to ALARO-1, SURFEX**

Description and objectives:

Currently 3 versions of ALARO physics package are used in the operational applications in LACE countries. Local teams are encouraged to replace the ALARO-0 baseline with the latest ALARO-1 version. Validation and tests of the newest ALARO-1vB version for the (pre-)operational will continue and experiments at resolutions around 2 km shall be performed to see benefits at higher resolutions. Support will be available.

For the model description of the surface/canopy layer and below, the externalized SURFEX framework of coupled models (for snow and ice, lake and sea, urban environment, forest and vegetation, heat and moisture fluxes in the soil etc.) is used ARPEGE and AROME. To profit from latest developments we decided to couple ALARO-1 with SURFEX version 8 which is implemented in the common code CY43T2.

In order to be able to use SURFEX with ALARO-1 physics package many issues have to be tackled. Modifications are needed in TOUCANS and SURFEX side (work of Rafiq Hamdi), scientifically consistent transition of ALARO from ISBA surface scheme to SURFEX should be also ensured. Screen level interpolation in SURFEX could soon become a blocking point for ALARO-1 verification and surface data assimilation. Attention must be paid not only to code differences, but also to different file formats and data-sets used. Computations of 'constant' surface fields from the same database for 'ALADIN-ISBA' as is used in SURFEX. Re-coding of screen level interpolations from ALADIN ISBA to SURFEX. Only after that work is done, we can proceed to more advanced SURFEX options (3 layer scheme, tiling, TEB, ...).

When moving to higher horizontal resolution, the parameterization of orographic shadowing in radiation implemented inside SURFEX (used in AROME) become important. It can be coupled also with ALARO-1vB physics (TOUCANS, ACRANEB2). Validation and sensitivity study of the parameterization of orographic shadowing in radiation with respect to the primary (radiation fluxes, temperature) and secondary (convection, low stratus in valleys, local circulation) effects has lower priority.

Actions in 2021:
- validation and operational use of ALARO-1vB in local applications;
- validation of ALARO-1 coupled with SURFEX ;

- screen level interpolations in SURFEX (possibly will be done in 2020?),

- computation of 'constant' surface fields from the same database used for SURFEX;
- preparations for the SURFEX usage in operational ALARO applications;

Proposed contributors, Estimated efforts: R. Brožková (Cz), N. Pristov (Si), M. Derkova (Sk), M. Dian (Sk), J. Mašek (Cz), 12.25 months (1+1 month LACE stay)

Planned timeframe: whole year

Planned deliverable: report

Action/Subject: **The ALARO-1 version**

Description and objectives:

The current well-tuned ALARO-1 version is ALARO-1vB (ALARO-1vA, plus modified screen-level interpolation, shallow convection scheme in TOUCANS, exponential-random cloud overlaps in radiation and cloud diagnostics, improved sunshine duration and direct solar flux at surface, 10m wind interpolation). This is now the base for further developments. Next step is to assemble the unsaturated downdrafts (an extra extension for the 3MT scheme), prognostic graupel and improved description of cloud cover when available.

In the second stage then all other planed developments; i.e. CSD, TOUCANS evolution, prognostic graupel, unified cloud treatment. CSD stands for the complementary sub-grid draft (research work of Luc Gerard, including both up- and down- drafts) scheme which enable a more realistic transition from parametrized to explicit convection when going to higher resolutions. Tuning of this scheme in the ALARO-1 environment will be needed.

The validation will be in the range from 5 km down to 1 km. Suitable validation test-beds (common with AROME and ARPEGE) for facilitating cross testing of various parametrizations should be also prepared. Clean comparison of ALARO and AROME can be done with 1D model.

Actions in 2021:
- *testing and tuning of non-saturated down draft inside ALARO-1vB*;
- code cleaning and reorganization, contribution for main code cycle;
- test and improve DDH for ALARO (new cycle new code structures);
- implementation and validation of 1D MUSC with ALARO;
- comparison AROME/ALARO in 1D model;

Proposed contributors: R. Brožková (Cz), J. Mašek (Cz), M.Hrastinski (Hr),

Planned timeframe: whole year

Planned deliverable: code, report, documentation

Action/Subject: **Interfacing physics parametrizations**

Description and objectives:

Impact study and validation of the physics-dynamics interface has high priority in ALADIN community (CPDY4). Scientific and practical constrains for redesign of physics interfaces (APL_AROME and APLPAR), which should enable the various physics packages (and also to exchange their individual parametrization schemes) are proposed. Actions are spread among many people, LACE contribution is to adopt ALARO part of computations in APLPAR routine. Radiation scheme in already in proper shape, code linked to turbulence and shallow convection should be analysed and adopted. Very demanding part on 3MT will follow after.

Action in 2021: Support to phasing TOUCANS scheme will be available.

Proposed contributors: R. Brožková (Cz), P. Smerkol (Si)

Estimated efforts: not planned

Planned deliverable: *code, documentation*

Action/Subject: Various products for users (forecasters)

Description and objectives:

Many requests from the user side, mainly forecasters, asking for additional forecast parameters has arrived. For this new features should be coded in post-processing part which would enable output of model fields. Continuation of this topic is foreseen on the base of good experience with enlarged convection diagnostics. The methods for lightening diagnostics have still to be evaluated and final solution should be proposed. Additional diagnostic meteorological parameters can be added: visibility, precipitation type (also wet snow, freezing rain), icing parameter, UV index, snowfall line, computation of real snow height.

Actions in 2021:
- validation implementation of precipitation type diagnostics (with freezing rain);
- further evaluation of lightning diagnostics;
- implementation and evaluation of the visibility computation (for ALARO and AROME);

Proposed contributors, Estimated efforts: J. Cedilnik (Si), C. Wittmann (At), F. Weidle (Au), N. Pristov (Si), M. Kolonko (Pl), M. Derkova (Sk), A. Simon (Sk), I. Mujic (Hr), K. Horvath (Hr), M. Tudor (Hr) 9.25 month (1 month stay PS + 0.5 CW)

Planned timeframe: whole year

Planned deliverable: code, documentation

Action/Subject: **Very Fine Resolution Experiments**

Description and objectives:

More and more teams are now able to perform VFR experiments with ALADIN NH-based models (with AROME and ALARO physics, within or without HARMONIE framework).

Few teams have started experiments at higher horizontal resolutions with AROME or ALARO-1 package (to be used also at the kilometric and hectometric scales). Several aspects on high resolution should be investigated (low stratus in valleys, initiation of convection over orography, etc.).

Study of the turbulence in the grey zone (resolved and parameterized description of eddies) will continue. The modification of shallow convection parameterization in AROME allows now to compute the turbulence parametrization scale-adaptively, the subgrid turbulent flux is extinguishing with higher horizontal resolution (100 – 1000 m) as the resolved turbulent flux increases. The effect of this modification is visible but is small and can be only part of final solution for the turbulence treatment in grey zone. Study will continue in direction of quasi 3D turbulence.

Actions in 2021:
- continuation of research on turbulence in the grey zone – currently no manpower
- preparation and validation of VHR model set-up, comparison ALARO-1 (4 km -2 km -1 km), AROME;
- tuning of TOUCANS for the dynamical adaptation for wind

Proposed contributors, Estimated efforts: J.Cedilnik (Si), P. Smolikova (Cz), A. Simon (Sk), I. Dominovic (Hr), M. Hrastinski (Hr), M. Szczech-Gajewska (Pl), M. Kolonko (Pl), Piotr Sekula (Pl) , B. Szintai (Hu) 19 months

Planned timeframe: whole year

Planned deliverable: report

Action/Subject: **Usage of SURFEX**

Description and objectives:

Various surface schemes are available in SURFEXv8 within cy43, in addition to standards one ISBA, TEB, Flake, also diffusion soil scheme (DIF), multi-layer explicit snow scheme (ES) and Multy-Energy Budget (MEB).

Actions in 2021:
- testing of the individual schemes;
- simulations with the FLake model;
~~- LAI analysis with SURFEX ISBA-Ags;~~ (moved to DA plan)
- CROCUS

Proposed contributors, Estimated efforts: M.Ličar (Si), V. Tarjani (Sk), 10 months

Planned timeframe: whole year

Planned deliverable: report

Action/Subject: **Coupling with sea surface / ocean**

Description and objectives:

Currently the sea surface is treated as a boundary condition represented by a rough surface (surface roughness without waves) whose temperature is prescribed from other models and/or analysis. The aim is to explore the benefits of a more realistic sea-atmosphere coupling where the state od sea surface is allowed to evolve with time during the forecast (temperature and waves) through coupling of the atmosphere with an ocean or/and wave model.

Actions in 2021:
- off-line coupling of ocean model NEMO with ALARO
- in-line coupling of wave model WWM with ALARO

Proposed contributors, Estimated efforts: Slovenian team, 8 months

Planned time frame: whole year

Planned deliverable: report

4 Summary of resources (numbers not final!)

Subject	Manpower	LACE stays	ALADIN stays
TOUCANS	**7**	**2**	
Radiation	**4**	2	
Cloud scheme	**4**		
Microphysics	**5**	**1**	
ALARO-0/ALARO-1/SURFEX	**12.25**	**2**	
ALARO-1	**/**		**0.25**
Physics interface	**-**		
Additional fields	**9.25**	**1**	**1**
VFR Experiments	**19**		
Usage of SURFEX	**10**		**1**
Coupling with sea surface / ocean	**8**		
Total:	**78.5**	**8**	**2.25**

LACE scientific stays:

- Mario Hrastinski (hr), TOUCANS – mixing length definitions, Prague, 6 weeks,
- Peter Smerkol (si), TOUCANS - code cleaning and validation, Prague, 2 weeks
- Piotr Sekula (pl), new diagnostic fields, Ljubljana, 4 weeks radiation and aerosols, Prague, 4 weeks
- Bogdan Bochenek (pl), grapuel, Prague, 4 weeks
- Martin Dian (sk), ALARO-1 coupling with SURFEX, Prague, 4 weeks, spring and autumn
- Ana Šljivić (hr), radiation, Prague, 4 weeks

ALADIN Flat-Rates Stays:

- *Luc Gerard: PH3.3 and PH3.5: update on cloudiness and CSD, 1 week, Prague for the end of 2019 postponed for 2020 (expected to be postponed for 2021)*

Stay related to OPLACE:

- *not yet defined for 2021*

5 Meetings and events

1) ALADIN Workshop and & HIRLAM All Staff Meeting, Slovenia, 2021
2) EWGLAM & SRNWP joined meetings, 2021
3) MUSC working week

6 Risk and constrains

The core team for the ALARO developments is a very small one. Effort and human resources should be increased in order to keep ALARO competitive in operation and climate applications. Candidate interested to work on convection (unsaturated downdraft, CSD) is searched.

It is crucial to continue good collaboration with other ALADIN/HIRLAM partners. Topics from this plan are included in ALADIN/HIRLAM/LACE rolling work plan 2021 in various working packages. Opportunity is cloud working group where LACE scientists could become more active. Everyone can also profit from a coordinated effort on post-processing work to obtain more diagnostic fields for the end-users and from common validation tool for VFR.

The pandemic of SARS-Cov-2 had disrupted work and travel. Much of the work was done in spite of that, but the networking and the number of fulfilled research stays was substantially reduced in 2020, therefore many stays have been postponed for 2021.