

C2I Workshop on ICON-LAM Setup & Experiments

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1 Introduction

The COSMO Priority Project C2I (Transition of COSMO to ICON) accompanies a transition phase of the COSMO consortium to the new modelling system ICON used in its limited-area mode (ICON-LAM). The aim is to ensure a smooth transition by taking step by step together.

After the official kick-off of the C2I project at the ICON Training Course in April 2018 the participating institutions started with the installation at their HPC systems. In order to facilitate the process of setting up experiments and to gather experiences jointly, it was decided to conduct a C2I workshop. For this workshop, the participants prepared their individual configurations (i.e., domain extension, grid spacing). The first part of the workshop was to offer an environment where the participants could perform simulations for their individual setup with the help of experienced ICON developers. The second part of the workshop gave the participants the free space to choose their own focus on how to continue with the ICON simulations. For example, they could try to run the simulations at their own HPC system, adapt their COSMO postprocessing to the ICON results or try different configurations. Experienced ICON developers assisted the participants also at this second part of the workshop. The theoretical part was kept very short, only an introduction on how to get started with ICON, an overview on ICON-LAM settings, a practical tutorial on visualization using GrADS and an exercise on Fieldextra were given.

The chance that was offered by the flexibility of the workshop was seized and the participants had very different focuses. This also highlights the difference to the ICON Training Course where well-prepared simulations are conducted and theoretical lectures are given.

2 Achievements for Brazil

The participants from Brazil, Gilberto Bonatti (INMET) and Reinaldo Silveira (SIMEPAR), chose a setup which closely resembles the current operational COSMO-7 setup for Brazil. Using a R3B8 grid, i.e. with 6.5 km effective resolution, the domain covers South America completely. The extent of the ICON-South-America domain can be seen in the top part of figure 1.

The key tasks that were set for the workshop are:

- Install `dwd-icontools` at xce DWD HPC,
- Remap initial and boundary conditions for South America domain at 6.6km,
- Setting up the namelist for ICON,

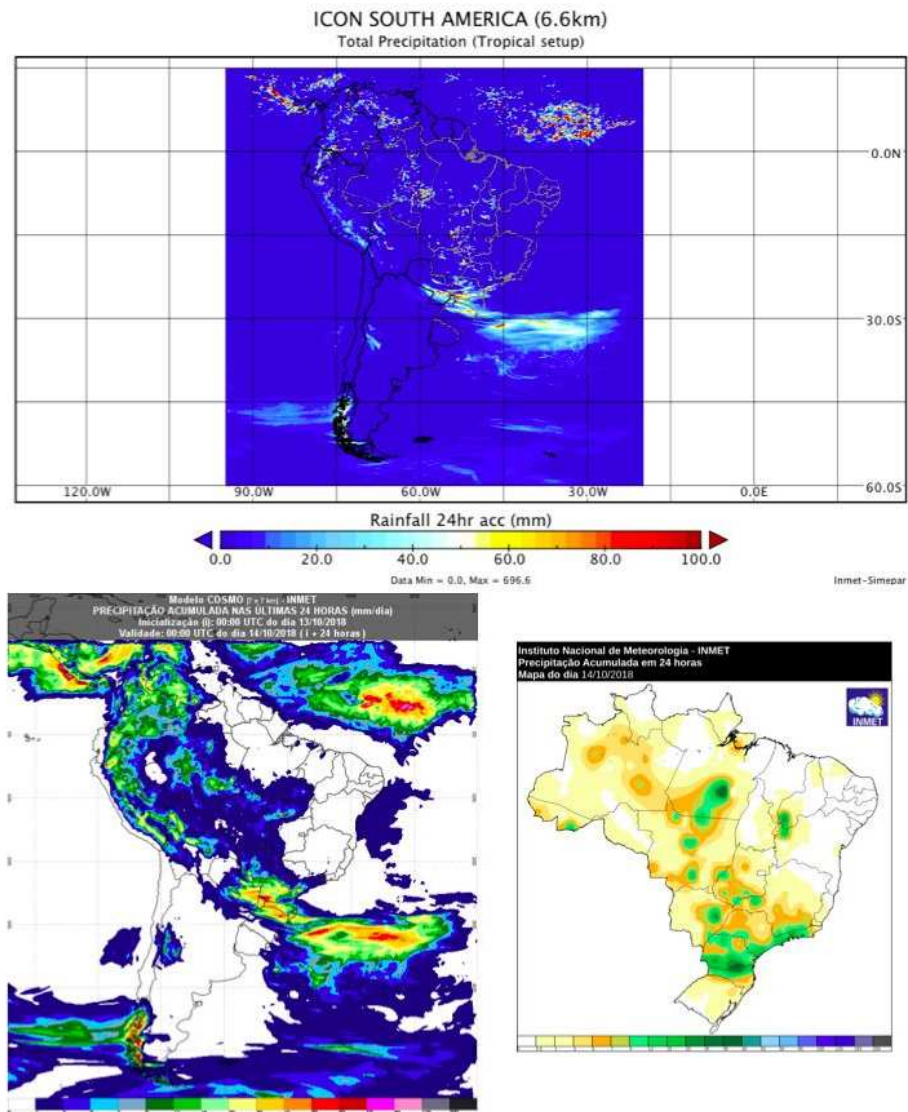


Figure 1: Comparison of the 24 h accumulated precipitation on 13 October 2018 between the Brazilian ICON 6.5 km domain (top), the operational COSMO forecast (bottom left) and measurements (bottom right). Please note the different color scales, i.e., very low values for ICON are in blue and for the other pictures in white.

- Run ICON with tropical setup and without tropical setup, using icon global lateral boundaries,
- Generate output and visualization, and
- Install and run ICON at INMET HPC.

These tasks were fulfilled and first results for ICON precipitation compared to the operational COSMO forecast and measurements can be seen in figure 1. While the ICON forecast shows, in general, similar features as the COSMO forecast, there is one particular region where ICON shows better results than COSMO. The area with precipitation measured which can be seen in the North Eastern part, i.e. in the South of Piauí state, is captured by ICON.

ICON was successfully run at the INMET HPC system. However, it was driven by already interpolated data. Installing and running the icontools remains an open issue.

3 Achievements for Israel

The participants from Israel, Pavel Khain (IMS) and Alon Shtivelman (IMS), chose a setup named ICON-C3 using a R2B10 grid, i.e. with 2.5 km effective resolution. First results using IFS initial and boundary conditions

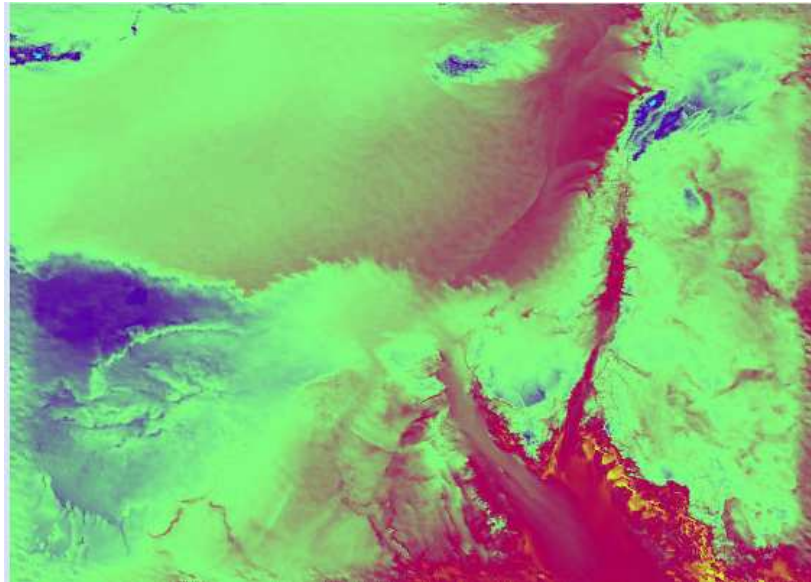


Figure 2: First results for the Israeli 3 km domain on 1 October 2018 with initial and boundary conditions from IFS.

can be seen in figure 2. The following tasks were achieved:

- ICON-C3 run on ECMWF computer, based on global IFS data, data retrieved using the `mars4icon_smi` script provided in the ICON code,
- ICON-D2 run on ECMWF computer, based on global ICON data (which is needed in the framework of the Priority Project T²RC²),
- ICON-D2 run on ECMWF computer, based on ICON-EU data,
- Visualization of triangles on ECMWF computer,
- Usage of FieldExtra for interpolating triangles on DWD computer, and
- ICON-C3 run on IMS computer, based on global IFS with previously remapped files.

As pointed out by the last bullet point, it was possible to run ICON at the IMS HPC system with previously remapped data. So far, a running version of the `icontools` at the IMS HPC computer could not be installed and remains an open issue.

4 Achievements for Italy

For Italy, members of four different institutions participated at the C2I workshop: Ines Cerenzia, Thomas Gastaldo, Andrea Montani and Virginia Poli from ARPAE-SIMC, Valeria Garbero from ARPA Piemonte, Edoardo Bucchignani and Paola Mercogliano from CIRA, and Francesca Marcucci and Riccardo Scatamacchia from COMET. Each of the institutions prepared an own setup for ICON. The achievements and focuses of the different institutions will be described in the following.

The participants from ARPAE-SIMC (Thomas Gastaldo, Andrea Montani and Virginia Poli) chose a R2B10 setup (2.5 km effective resolution) on a domain that covers Italy and the surrounding Mediterranean regions. The extent of the domain can be seen in figure 3. The following achievements were reached:

- Running ICON-LAM on DWD HPC,
- Compilation of `icontools` & ICON on ECMWF HPC,
- Run on ECMWF HPC,
- Compilation of `ICONTTOOLS` & ICON on CINECA HPC, and
- Run `iconremap` on CINECA HPC.

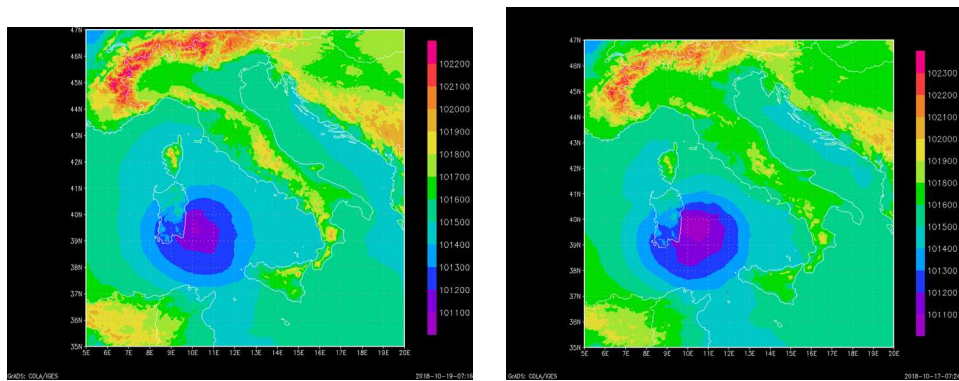


Figure 3: Mean sea level pressure on 21 September 2018, 3 UTC, for the ARPAE-SIMC domain at 2.5 km. Initial and boundary data are derived from global ICON forecast (left) and IFS forecast (right). Please note the slightly different color scales.

Although running ICON on CINECA HPC resulted in an error, a fix for the particular error is well known and further tests will be performed after the workshop. As visible in the list of achievements, a clear focus was set to port ICON to different available HPC systems and get it ready for further studies.

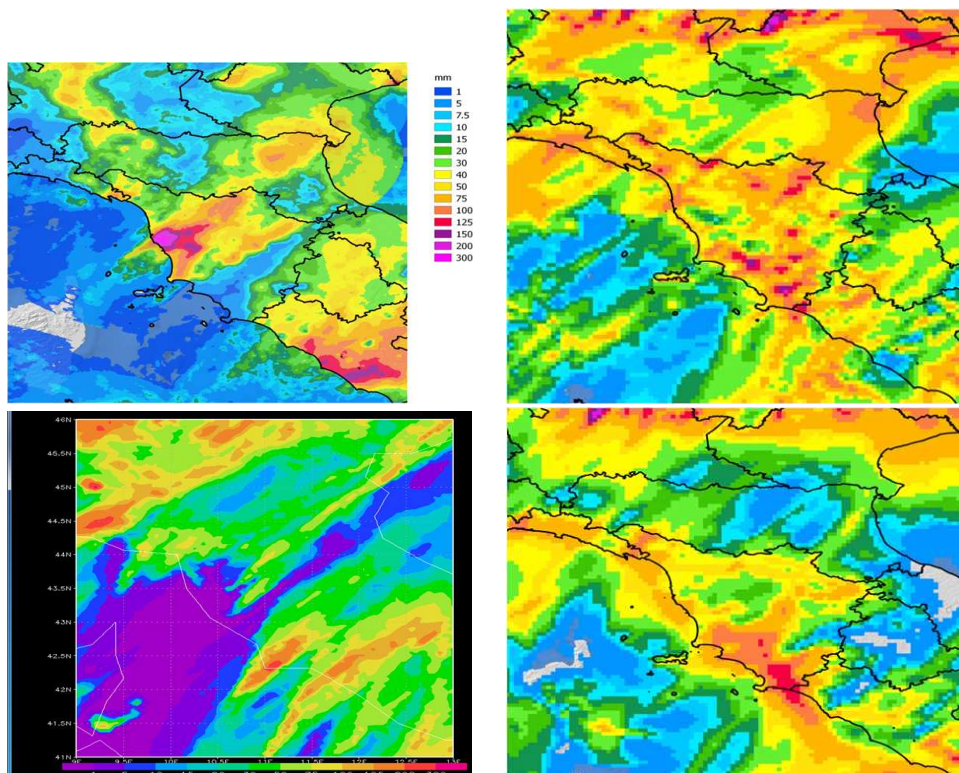


Figure 4: Accumulated precipitation in the Emilia Romagna and Tuscany region on 14 September 2017 from radar measurements (top left), ICON 5 km (bottom left), COSMO-I5 Tiedtke (top right) and COSMO-I5 Bechtold (bottom right). Please note the different color scales!

For a team from ARPA Piemonte and ARPAE-SIMC (Valeria Garbero and Ines Cerenzia), a large domain covering Italy and adjacent regions on a R4B8 grid (i.e. 5 km effective resolution) was chosen. For the visualizations, however, only a subregion centered around Tuscany and Emilia Romagna is displayed (see figure 4). The image provides a first comparison between the ICON results, measurements and results from two different COSMO configurations using Tiedtke and Bechtold convection respectively. The strong maximum that was measured near Livorno was not captured by any of the simulations. Taking the very different color scale into consideration, other features in the measured precipitation are reproduced by ICON.

A strong focus was set on preparing IFS initial and boundary data. A workaround was found for the interpolation problems which will be further elaborated in the section concerning problems and open issues. The `mars4icon_smi` script which is provided with ICON to retrieve global IFS data was adapted for limited area retrievals. Open issues with retrieving IFS data on limited-area domains are also further discussed in the problems and open issues section.

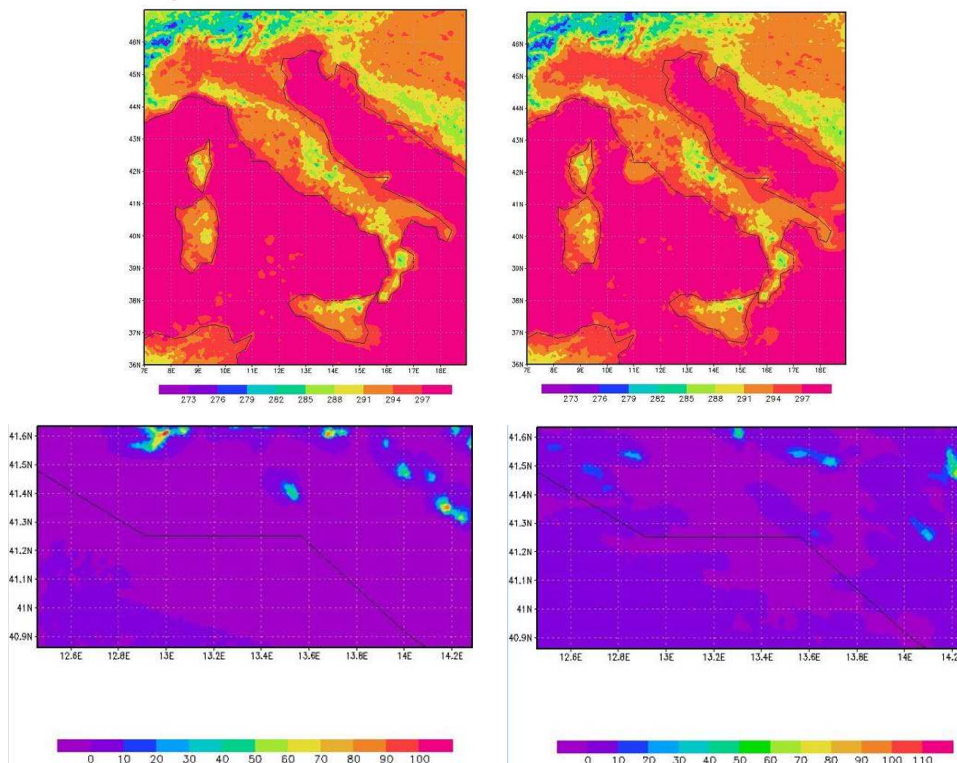


Figure 5: Results for the 2 m temperature on 21 September 2018, 21 UTC, from a simulation over the whole Italian area at 7 km, driven by ICON (top left) or IFS (top right). Total precipitation for the high-resolution domain driven with ICON initial and boundary conditions (bottom left) and IFS initial and boundary conditions (bottom right).

The participants from CIRA, Edoardo Bucchignani and Paola Mercogliano, prepared two different setups. The first domain covers the whole Italian area at 6.5 km effective resolution (R3B8) and is forced both by ICON global and IFS data. The simulations were performed for 21 September 2018. A comparison between the simulations with different forcing data in terms of 2 m temperature at 21 UTC can be seen in the top row of figure 5. The strongest differences are in the coastal areas which could be due to the interpolation of SST and soil temperature or differences in the land mask between the driving model and ICON-LAM. As pointed out before, the interpolation procedure for IFS data needs to be investigated further.

The second domain is a small high-resolution (R2B11, 1 km) domain centered around the Campania region. Initial and boundary conditions were saved in NetCDF format. Some problems were encountered due to name conventions. The dictionary for lateral boundary conditions (`dict.latbc` file) had to be modified. Forcing data was provided both by ICON global and by IFS. In the bottom row of figure 5 the total precipitation as simulated by ICON driven with ICON global data (left) and IFS data (right) is shown. Convection was triggered close to the Northern and Eastern boundaries in both cases. The position of the individual convective cells, however, is different between the two simulations.

Francesca Marcucci and Riccardo Scatamacchia from COMET prepared two different setups. The first setup called ICON-ME at 5 km (R2B10) covers the whole Mediterranean and adjacent regions. It resembles the COSMO-ME setup. The extent can be seen in the left part of figure 6 (although the land contours are missing). The first results displayed in figure 6 were achieved with the global IFS initial and boundary conditions prepared by DWD for the workshop.

The second domain called ICON-IT uses a R9B8 grid (2.2 km effective resolution) which resembles the current COSMO-IT configuration. Initial and boundary conditions from the previous ICON-ME simulation are used. The extent of the domain and first results are depicted in the right part of figure 6.

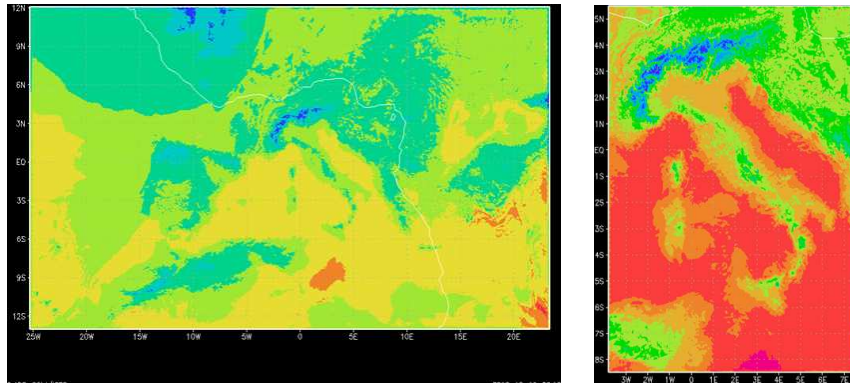


Figure 6: Results for the ICON-ME domain at 5 km (left) and the high-resolution ICON-IT domain at 2 km (right). The simulations of 21 September 2018 were driven by IFS data.

As hinted by the choice of the setup, the first focus was set on running the high-resolution ICON-IT as an offline-nest inside the ICON-ME domain. A second focus was set on preparing and retrieving IFS initial and boundary conditions in an efficient way. The operational stream of IFS data for COMET provides data on a limited-area frame grid. Several adaptations are necessary for this data to be usable as boundary data for ICON. Among the changes are the calculation of soil moisture index (SMI), adaptation of pressure levels (i.e., only z or ϕ at surface are needed, other z and ϕ should not be present) and U and V must be remapped to U and V instead of VN (wind normal to ICON triangle edges).

Tests were performed on the ECMWF HPC system. Using a workaround for a bug, data from the operational stream was tested with and without using a frame grid in the remap process. Technically, the tests were successful. The results, however, were not correct, most probably because of the workaround.

5 Achievements for Poland

Witold Interewicz from IMGW chose a R2B10 (2.5 km effective resolution) grid covering Poland and adjacent regions. The extent of the domain can be seen in figure 7. After a first try with a configuration without using a reduced radiation grid, it was decided to rerun the grid generator and try a simulation for 21 September using also a reduced radiation grid.

A focus was set on running a high-impact weather situation on 9 and 10 August 2017 and adapting the COSMO postprocessing environment from IMGW to the ICON-LAM simulation. Figure 7 documents the success of this effort. The top figure shows the 24 h precipitation in combination the cloud cover on 10 August 2017, 0 UTC. The bottom figure depicts the wind speed and direction for the same time.

6 Achievements for Romania

The main focus of Cosmin Barbu and Rodica Claudia Dumitrache was to run ICON in a similar configuration as the current operational configuration at NMA and gain experience with ICON which is necessary for the future support activities of NMA.

The setup for Romania includes a 6.5 km (R3B8) domain covering a large area around Romania and a second, high-resolution domain at 2.8 km (R7B8) covering Romania. The extent of the high-resolution domain can be seen in figure 8.

Due to the necessary HPC resources, one of the questions that were investigated was, whether the 6.5 km domain is beneficial (or necessary) as an intermediate step between the global ICON data from DWD and the high-resolution domain. The alternative could be to use the global ICON data directly as initial and boundary condition for the high-resolution domain. This can be justified as the global ICON data contains the solution of the 6.5 km ICON-EU nest. Figure 8 shows results from a high-resolution simulation directly nested into ICON global (top left), a simulation that uses a 6.5 km limited-area simulation as an intermediate step (top right) and the difference between the results (bottom). It turns out that local differences in the lowest model layer temperature of up to 2° occur. A strong difference of up to 4° is visible at the Black Sea. The reason for this strong, unexpected difference has to be investigated in more detail. In general, further

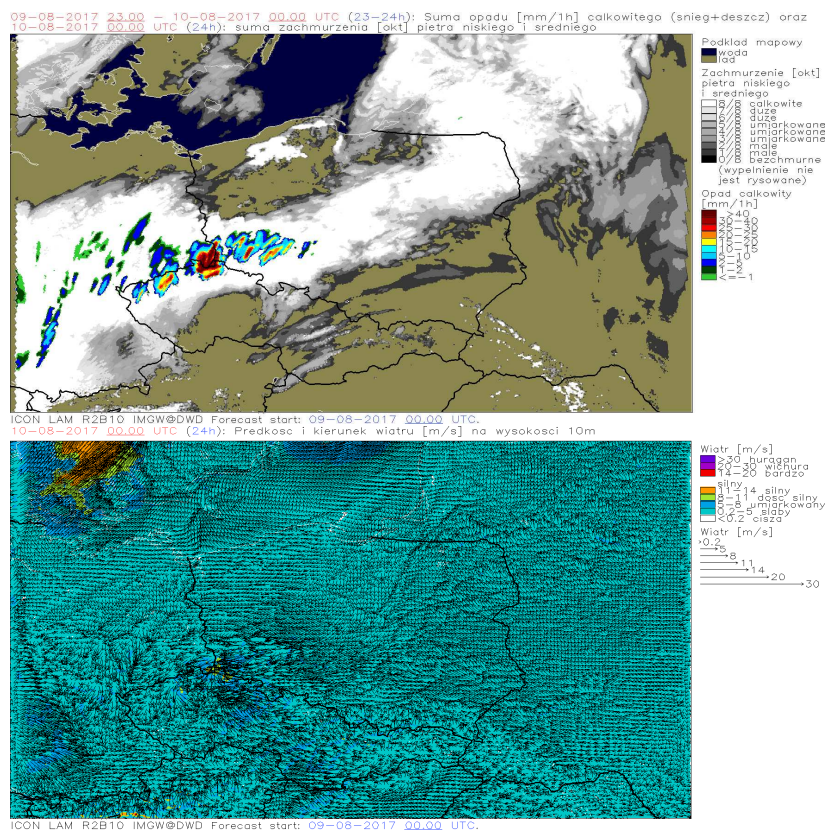


Figure 7: Total cloud cover and precipitation (top) and wind speed and direction (bottom) after 24h of simulation on 10 August 2017, 0 UTC, for the Polish 2.5 km domain.

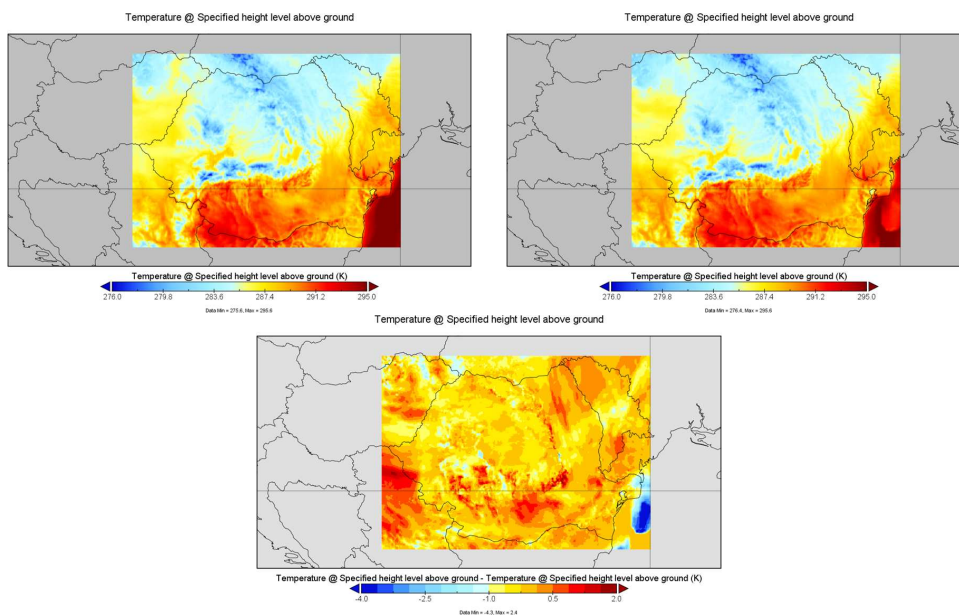


Figure 8: Results for 2m temperature on 21 September 2018 in the Romanian (NMA) high-resolution domain. The 2.8 km simulation is directly driven by global ICON data (top left) or with an intermediate step, i.e., a 6.5 km simulation of the Romanian domain (top right). The bottom figure shows the difference between the results.

cases and comparisons with measurements have to be taken into account to reach a conclusion.

7 Achievements for Russia

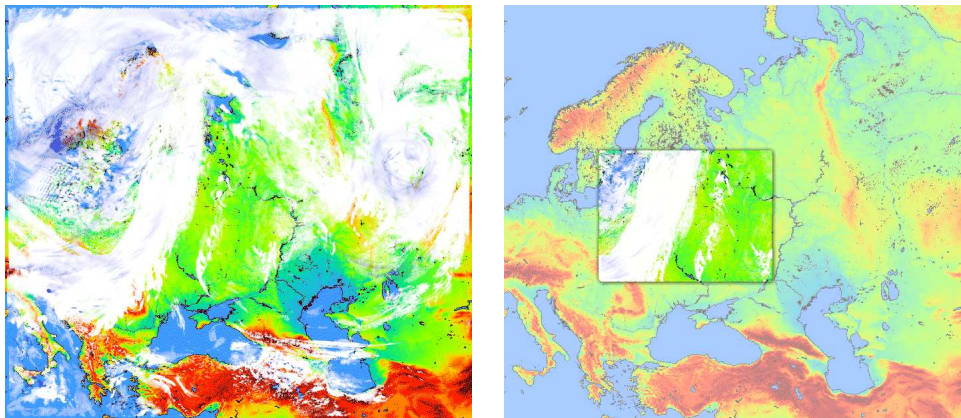


Figure 9: Total cloud cover (white) and accumulated 48 h precipitation (blue) on 21 September 2018 for the 6.5 km Russian domain (left) and the 3.2 km nested domain (right).

The participants from RHM, Denis Blinov and Alexander Kirsanov, prepared one large domain named ICON-RU7 which uses an R3B8 grid (6.5 km effective resolution). The extent of ICON-RU7 can be seen in figure 9. The left part of the figure shows results of an ICON-RU7 simulation while the right part shows the topography in combination with results from a nest which will be described in the following. An online two-way nest named ICON-RU3 (R3B9, 3.2 km) was added to cover most of the densely populated regions of Russia. The extent is visualized by the frame in the right part of figure 9.

Figure 9 shows the total cloud cover (in white) combined with accumulated 48 h precipitation (in blue) on 23 September 2018, 0 UTC. Minor differences in the structure of the cloud fields and the precipitation are visible, a quantitative comparison has not been performed.

In the current operational setup, RHM is performing comprehensive air quality forecasts with COSMO-ART (including chemistry and secondary aerosol formation). This is done for a small domain around the Moscow region. For this reason, first tests with ICON-ART have been performed. A simulation of an artificial volcano eruption ('The Great Moscow Eruption') near Moscow with ICON-LAM-ART has been performed successfully.

Additionally, tests have been performed at the RHM HPC system. ICON and the icontools have been compiled, data provided at the workshop as well as the actual data sent to RHM were remapped and ICON-LAM simulations were performed. ICON-ART worked with the binary compiled at DWD also at the RHM HPC (as the systems are very similar). The ICON-ART binary compiled at RHM, however, showed some problems, probably related to the xml library installed at RHM.

8 Achievements for Switzerland

Guy de Morsier and Carlos Osuna from MCH chose a double-nested setup at very high resolutions with the following domains:

- Swiss R19B08 (1km), the extent is shown in the top part of figure 10,
- Alps R19B09 (500m), the extent is shown in the bottom part of figure 10, and
- a small domain around Zurich, Zrh R19B10 (250m).

For the test case of 21 September 2018, several configurations using different initial and boundary conditions, etc., have been tested. The following achievements were reached:

- Could compile both icon and icontools with gcc and cray on 2 CSCS computers,
- Remap ICON (global) & IFS data to obtain IC and LBC,
- Swiss domain (1km) could run with ICON +48h and +33h with IFS IC and LBC, and
- 1 nest with Swiss and Alps with ICON IC and LBC to +12h.

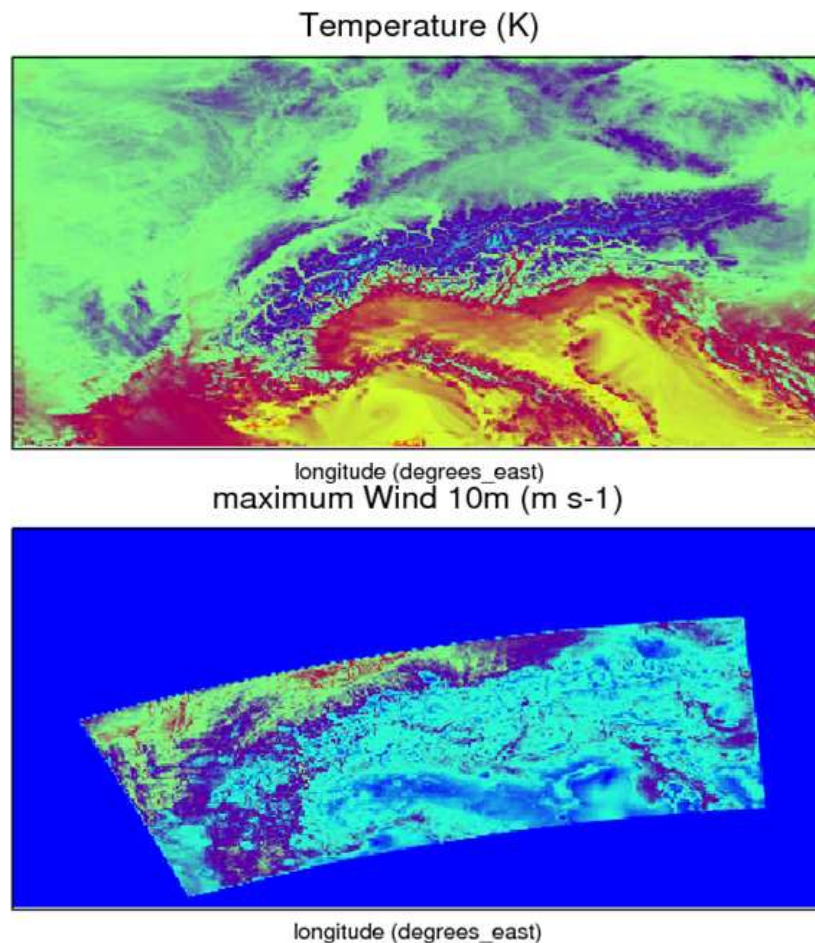


Figure 10: First results for the large Swiss 1 km domain (top) and the nested 500 m region following the arch described by the Alps (bottom).

Unfortunately, a simulation with the 250 m nested region around Zurich was not successful, the errors are being investigated.

9 Problems Encountered & and Open Issues

The usage of ICON for high-resolution limited-area simulations with the NWP physics package has just started. It was expected that some problems occur at a workshop where this mode of ICON is used in very different configurations. In this section, we want to provide an overview on the most pressing problems that were encountered and an outlook on possible solutions is given.

- **Interpolation**

The estimation of coefficients for the RBF interpolation in the `icontools` (`intp_method = 3`) did not work as intended for masked fields. This bug resulted in interpolated fields as visualized in figure 11. During the workshop, the most convenient solution was to use another interpolation method, namely nearest neighbor (`intp_method = 4`).

The development version of the `icontools` already contains a fix for this behavior. A new version will be prepared and distributed within the next weeks.

- **Visualization of ICON results on triangular grid**

It is not an easy task to visualize ICON data on the native triangular grid. Especially for interpolation problems as described above, it is necessary to take a look at the data on the triangular grid. During the workshop, this was done by adapting a NCL script to the needs.

There are multiple ways to visualize ICON data on triangular grid. Unfortunately, `GrADS` which is probably the most used visualization software in `COSMO` can not be used for this task. For example,

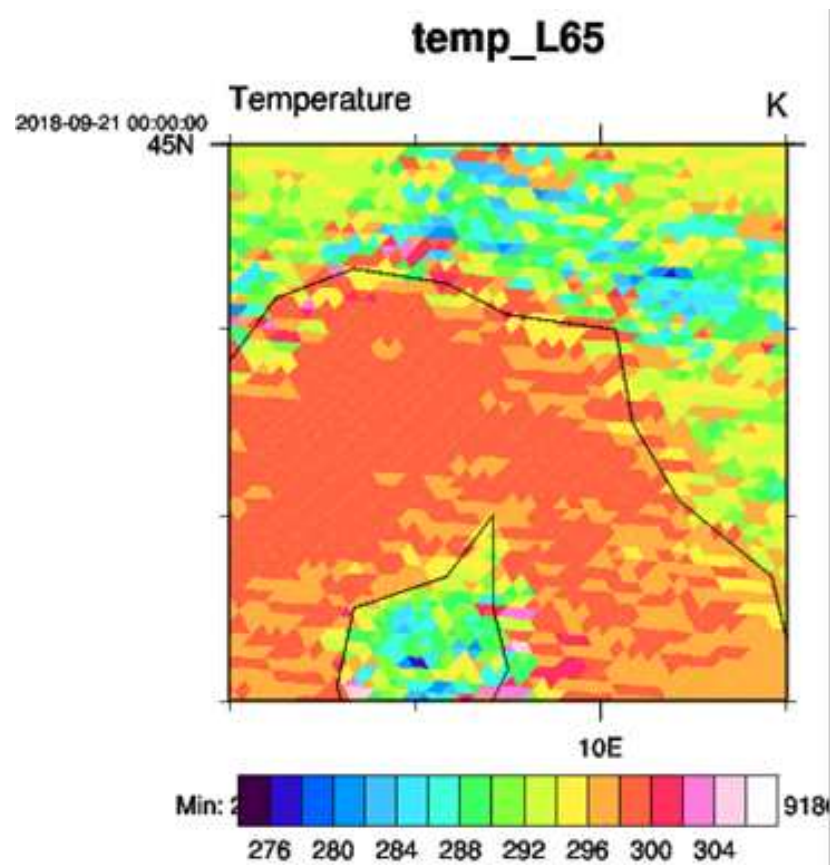


Figure 11: Example for an interpolation bug in iconremap of IFS data that many of the participants were facing. The visualization was performed with NCL on the native triangular ICON grid.

NCL or Python can be used and the COSMO partners should share their scripts and experiences in the future.

- **Retrieval of limited-area IFS data**

Many of the COSMO members are using IFS data from ECMWF as initial and boundary data for their forecasting system. A script to retrieve ICON-conform IFS data is provided as a part of the source code (named `mars4icon_smi`). The original intention of this script, however, is to retrieve global initial data. Hence, the files are much larger than they need to be for limited-area applications. The scripts also performs preprocessing of the data, i.e. soil moisture index (SMI) is calculated and subsequently used instead of the soil water content. This makes the resulting soil moisture more independent from soil types, which can be different between IFS and ICON. It turned out that adapting the script to limited-area mode retrieval created other problems. Two horizontal grids turned up in the file retrieved for the limited area which made the `icontools` crash. In addition, the SMI did not show up in the retrieved data.

A bug has been identified within the underlying I/O library CDI which caused the problem with two horizontal grids. A bugfix will be provided as soon as it is available and tested. In general, a limited-area option has to be added to the `mars4icon_smi` script. As this is important for several COSMO members, a task force should be established that adds the features needed by COSMO to the `mars4icon_smi` script.

- **generatingCenter and generatingSubCenter**

Currently, the `generatingCenter` and `generatingSubCenter` of grib files used for ICON has to be DWD (i.e., 78 and 255). This can, if necessary, be controlled during the grid file generation. If the center and subcenter are different, they have to be overwritten by a namelist switch in ICON.

The changes necessary to accept also data from other centers will be investigated.

- **Portability of ICON and icontools**

Many participants pointed out their problems in porting ICON and the `icontools` to a new HPC platform.

In most of the cases, two reasons are responsible. One is the confusing realization of the configure environment of ICON and confusions due to the multiple Makefiles of the `icontools`. The other reason

are the requirements to the software stack. Recent compiler versions in combination with multiple libraries that should be built with the same compiler version are necessary. Sometimes, it is even a combination of both reasons. There are efforts at DWD and MPI-M to increase the portability of the codes.

10 Summary and Outlook

Despite the previously mentioned problems that were encountered during the workshop, each group was able to achieve a great deal of progress with ICON-LAM. Each of the groups was able to successfully perform simulations with their chosen configuration. In addition, several groups managed to run ICON also on their HPC system and/or on the ECMWF HPC system. The COSMO members are now well-prepared to start with a testing phase of ICON at their institutions and the second phase of the Priority Project C2I.

Besides that, several achievements with respect to pre- and postprocessing were achieved. The retrieval of global IFS data as initial and boundary condition has worked and a more efficient way to retrieve limited-area data is being investigated. Some COSMO members were able to drive an ICON-LAM simulation with the ICON data that they receive routinely from DWD for their COSMO forecasts. The feasibility of adapting a COSMO postprocessing suite to ICON was also proofed.

The C2I Workshop on Setup & Experiments successfully provided an entry point for the individual ICON-LAM simulations of the COSMO members. Besides the achievements presented so far, the workshop also fostered the collaboration between the COSMO partners. Individual achievements are shared with the other COSMO members and a close network is established that eases a joint transition phase to ICON-LAM.