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It would be no exaggeration to say that the Consortium for Small-Scale Modelling finds itself at a crossroad. The limited-area model COSMO will be abandoned in a few years' time in favour of ICON-LAM, the Limited Area Mode of the comprehensive modelling framework ICON (ICOsahedral Nonhydrostatic).

A change of the basic modelling tool is not an easy step. It causes many problems of technical, scientific and organizational character, and the Consortium works hard to solve them. In order to ensure a smooth transition from the COSMO model to ICON-LAM, the priority project C2I was launched in 2017 (http://www.cosmo-model.org/content/tasks/priorityProjects/c2i/default.htm). As a result of the project implementation, all Consortium members should be able to perform deterministic forecast with ICON-LAM. The target date is the first quarter of 2022.

In-depth discussions of recent results, ongoing work and challenging issues, of both scientific and management nature, took place during the last COSMO General Meetings. Since July 2017, when previous COSMO Newsletter (No. 17) was issued, two meetings took place. The 19th meeting was held in Jerusalem, Israel, 11-14 September 2017, and the 20th meeting in St. Petersburg, Russia, 3-5 September 2018. Some information, including the meeting agendas and the presentations made at the plenary and parallel sessions, is available at the COSMO web page,see http://www.cosmo-model.org/content/consortium/generalMeetings/default.htm.

I would like to thank all researchers who contributed to the current issue (No. 18) of the COSMO Newsletter. It is worth noting, however, that the current issue contains four contributions only, less than any other Newsletter published so far. The interest to publish in the COSMO Newsletter is clearly decreasing, and this trend may well continue in the future. A number of remedial measures have been proposed, and steps are being taken in an attempt to improve the situation. The future of COSMO Newsletter remains largely unclear, necessitating further discussions of the COSMO publication policy.

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Sensitivity of precipitation forecast skill to the parameterisation of moist convection in COSMO-based ensemble systems

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1 Introduction

The parameterisation of convection in limited-area models is an important source of uncertainty as regards the spatio-temporal forecast of precipitation. As for the limited-area model COSMO, hitherto, only the Tiedtke convection scheme (Tiedtke, 1989) was available for the operational runs of the model in convection-parameterised mode. In addition to this the Bechtold scheme, implemented in ECMWF global model, has recently been adapted for COSMO applications. The development and implementation of ensemble systems in which different convection schemes are used, provides an opportunity to upgrade state-of-the-art probabilistic systems at the convection-parameterised scale. The sensitivity of the COSMO model forecast skill to the use of either the Tietdke or the Bechtold (Bechtold et al., 2008; 2014) schemes is assessed by performing different sets of experiments. This study is part of the CIAO COSMO Priority Task.

The performance of COSMO model run with the different schemes is investigated in ensemble mode with particular attention to the types of forecast errors (e.g. location, timing, intensity) provided by the different convection schemes in terms of total precipitation.

A 10-member ensemble has been run for approximately 2 months with the Bechtold scheme, using the same initial and boundary conditions as members 1-10 of the operational COSMO-LEPS ensemble system (which has 20 members, all run with the Tiedtke scheme). The performance of these members is assessed and compared to that of the system made of members 1-10 of COSMO-LEPS in terms of total precipitation prediction.

Finally, the performance of an experimental 20-member ensemble system (which has 10 members run with the Bechtold plus 10 members run with the Tiedtke scheme) is compared to that of operational COSMO-LEPS over the 2-month period. The new system turned out to have higher skill in terms of precipitation forecast with respect to COSMO-LEPS over the period. In this approach the use of the Bechtold scheme is proposed as a perturbation for the COSMO-LEPS ensemble, relatively to how uncertainties in the model representation of the cumulus convection can be described and quantified.

2 System description and methodology of analysis

Some experiments have been performed, in order to evaluate the COSMO model performance in ensemble mode when it is run either with the Tiedtke or the Bechtold scheme, so as to assess overall abilities and shortcomings of the system (Vasconi, 2017). Firstly, we have built a test suite to run a 10-member ensemble with the Bechtold scheme (referred to as Cleps-10B), which uses the same initial and boundary conditions as members 1-10 of the operational COSMO-LEPS (which has 20 members, all run with the Tiedtke scheme). This suite has been run from 28th March to 31th May 2017 with an integration domain covering Central-Southern Europe and Italy (shown in Fig. 1), at the horizontal resolution of about 7 km and 40 vertical layers, and with a 132-hours forecast range, always starting at 00 UTC. In particular, the sensitivity of the ensemble system to the different parameterisation schemes has been assessed by comparing the performance of Cleps-10B to that of Cleps-10T, which is the 10-member ensemble provided by members 1-10 of COSMO-LEPS, the operational ensemble system of the COSMO consortium, over the verification period.

A further step in the study of COSMO ensemble system sensitivity to different formulation of moist convection is the implementation of a new probabilistic system, hereafter Cleps20bt, in which a multi-physics approach in the model representation of the cumulus convection is followed. This system is generated by adding the members of Cleps-10B to members 11-20 of COSMO-LEPS. Therefore, Cleps20bt has 10 members run with the Bechtold scheme plus 10 members run with the Tiedtke scheme and no duplication of initial and boundary

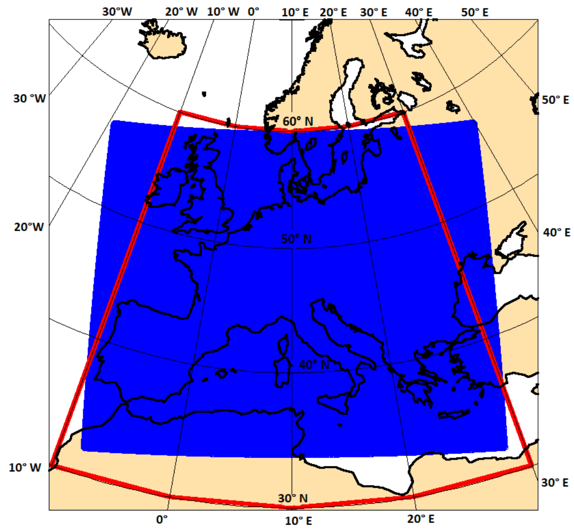


Figure 1: COSMO-LEPS integration domain (blue area) and clustering area (inside the red line).

Acronym	Ensemble size	Convection scheme	ICs-BCs
COSMO-LEPS	20	Tiedtke	from ECMWF-ENS
Cleps-10B	10	Bechtold	the same as 1-10 of COSMO-LEPS
Cleps-10T	10	Tiedtke	the same as 1-10 of COSMO-LEPS
Cleps-20bt	20	Bechtold + Tiedtke	the same as COSMO-LEPS

Table 1: Main features of the ensemble systems of Section 2

conditions. The basic idea of the Cleps20bt implementation is that certain closure parameters used in model formulation (as for the moist convective processes) may be based on approximate physical knowledge. As a consequence their values may be somewhat arbitrary, or they may have been tuned to give optimal results for test cases that are not necessarily representative of more general applications and/or for applications at high resolution. A summary of the ensembles features is presented in Table 1.

The performance of the ensemble systems was analysed by considering the probabilistic prediction of 6-h cumulated precipitation exceeding a number of thresholds for forecast up to 132 hours over the 2-month period. Since precipitation has a high-spatial variability, a high-density network, made of about 1000 stations

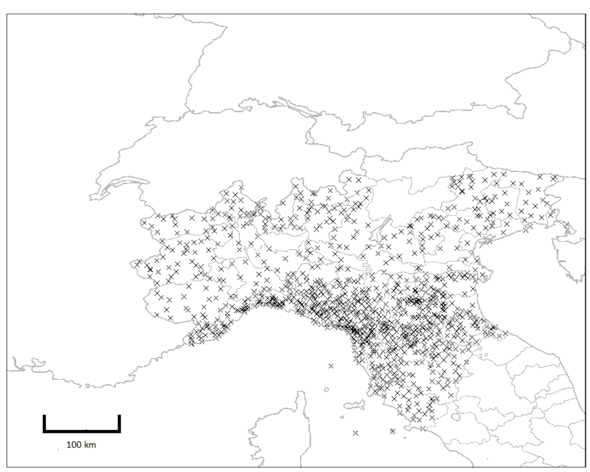


Figure 2: Observation network used for verification.

over Northern Italy (Fig. 2), has been adopted in order to assess the predictive skill of the ensemble systems. For the comparison of the model forecasts against station reports the grid point closest to the observation one is selected. In particular the performance of the different ensemble systems of Table 2 is examined for six different 6-h cumulated precipitation thresholds: 1, 5, 10, 15, 25, 50 mm/6-h. Several thousands of events were reported for the first two thresholds, and several hundreds for the 15 mm/6-h threshold. On the other hand it is immediately worth pointing out that, when considering the highest thresholds (25, 50 mm/6-h), a low number of occurrences, even below 10 for the 50 mm/6-h, was found over the verification period. As a consequence this does not allow any solid statistical conclusion on the effective performance of the system for these events over the period.

For each forecast range, the model performance has been evaluated by computing the following "traditional" probabilistic scores (Wilks, 1995): the Brier Skill Score (BSS), the Ranked Probability Skill Score (RPSS), and the Percentage of Outliers (Buizza, 1997). A summary table of the verification features is reported in Table 2.

Verification features	
variable:	6-h cumulated precipitation (00-06, 06-12,..UTC);
Period:	from 28th March to 31th May 2017 (about 60 days);
region:	Northern Italy;
method:	nearest grid-point; no-weighted fcst;
obs:	non-GTS network, no obs error;
fcst ranges:	0-6 h, 6-12 h,..., 126-132 h;
thresholds:	1, 5, 10, 15, 25, 50 mm/6 h;
systems:	Cleps-10B vs Cleps-10T, Cleps20bt vs COSMO-LEPS;
scores:	BSS, RPSS, Percentage of Outliers.

Table 2: Main features of the verification configuration for the ensembles

3 Comparison of 10-member ensemble system run with different schemes

The BSS (Brier Skill Score) for the Cleps-10T and Cleps-10B is presented in Fig.3. A 24-h running mean is here applied to "smooth" the diurnal cycle in model performance, improving the readability of the plot. This score tries to represent a quantitative estimate of the added value detectable in precipitation prediction by using the model forecast rather than a reference one (in this case, climatology of the observed sample over the verification period). The attention has been focused on two thresholds (1 mm/6-h and 15 mm/6-h), which have a quite large number of occurences (higher than 1000 for the former, some hundreds for the latter) over the verification period.

It is worth noticing that the BSS shows clearly the loss of predictability with increasing forecast range for both systems. The model forecast has added value with respect to the reference climatology up to +120 hours. However the plot shows a different skill of the 2 systems when different thresholds and forecast ranges are considered. Over the verification period, Cleps-10T performs generally better than Cleps-10B for the lower threshold (1 mm/6-h), while the opposite is true in high precipitation rates prediction for forecast ranges from 3 days onwards. In other words, the ensemble systems seem to describe different types of forecast errors, possibly related to the different convection schemes (Vasconi, 2017).

In addition to this, the RPSS (Ranked Probability Skill Score) of this system has been computed for different forecast ranges and compared to that of COSMO-LEPS during the same period. The plot in Fig. 4 shows a better performance of Cleps-10T for the forecast ranges up to +48 hours.

These results can be seen consistent with the theory according to which the ensemble systems which are run using either convection schemes can describe a larger variety of uncertainty and errors in precipitation prediction.

Finally, the skill of the two systems has been assessed in terms of Percentage of Outliers (that is the cases in which observed rainfall value is not inside the ranges of possible values predicted by the ensemble members, Fig. 5). Firstly it is worth pointing out that the total percentage of outliers (left panel) for both systems tends to decrease with increasing forecast range because of the increasing spread with time between the ensemble members. A better performance of Cleps-10T, which has a lower number of outliers than Cleps-10B, can be noticed, in particular for the earlier forecast ranges. The right panel of Fig. 5 represents respectively the fraction of points in which observations lie above/below the range of predicted values by the ensemble system.

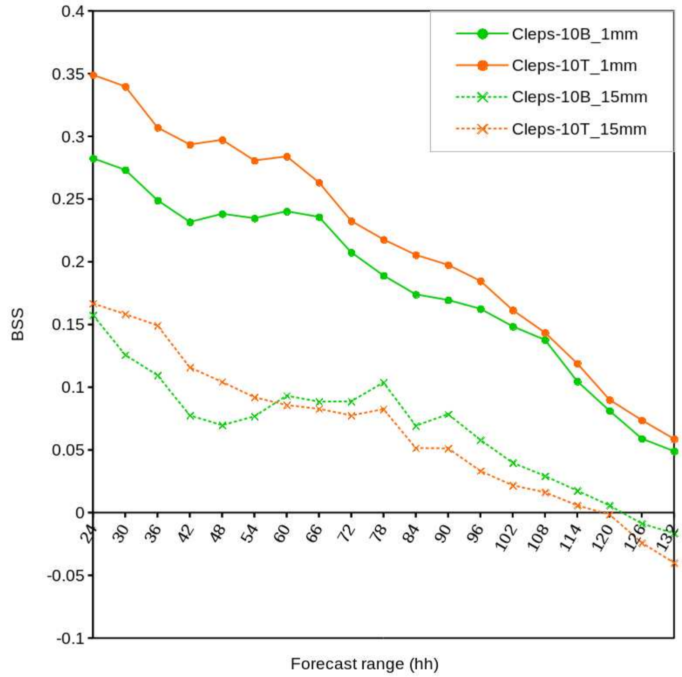


Figure 3: 24-h running mean of BSS in Cleps-10T and Cleps-10B (orange and green line respectively) for 1 mm/6-h and 15 mm/6-h (solid and dashed line respectively) thresholds.

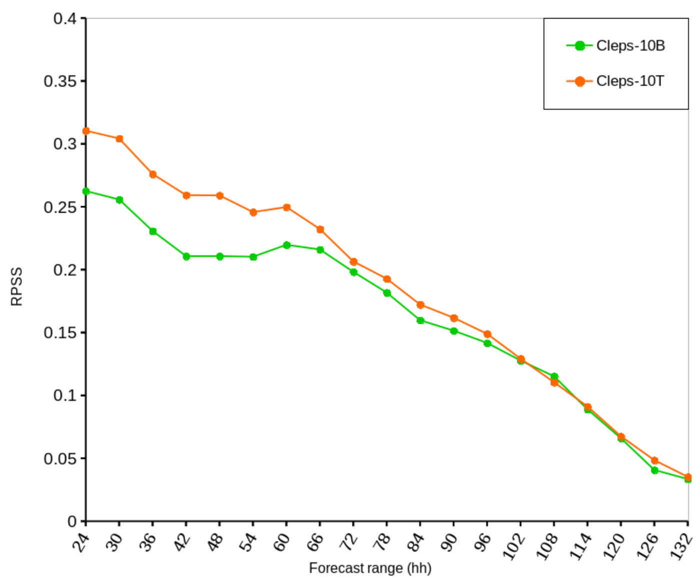
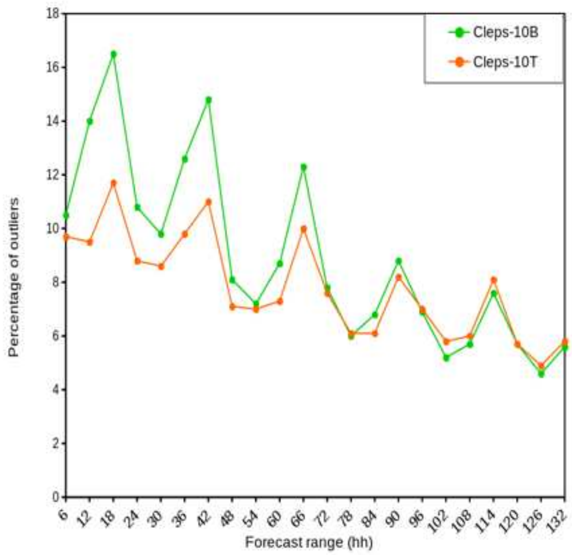


Figure 4: 24-h running mean of RPSS in Cleps-10T (orange line) and Cleps-10B (green line).

A large amount of outliers below the minimum forecast value, indicative of an overestimation of minima of precipitation amount by Cleps-10B runs, can be seen. In particular the percentage of outliers lying below the minimum predicted values is higher for Cleps-10B than for Cleps-10T for all the forecast ranges studied. This seems to indicate that members with the Bechtold scheme tend to produce some light prepitation also when it is not observed. On the other hand, the fraction of analysis point above the maximum tends to be similar or slightly lower for Cleps-10B. This excessive drizzle effect could be due to the shallow convection treatment adopted by the Bechtold scheme. This scheme in fact allows "shallow convection" to produce precipitation, whereas the Tiedtke scheme does not. It is possible that further tuning of the Bechtold scheme, when adopted at high resolution, is necessary to address this “drizzle” issue.



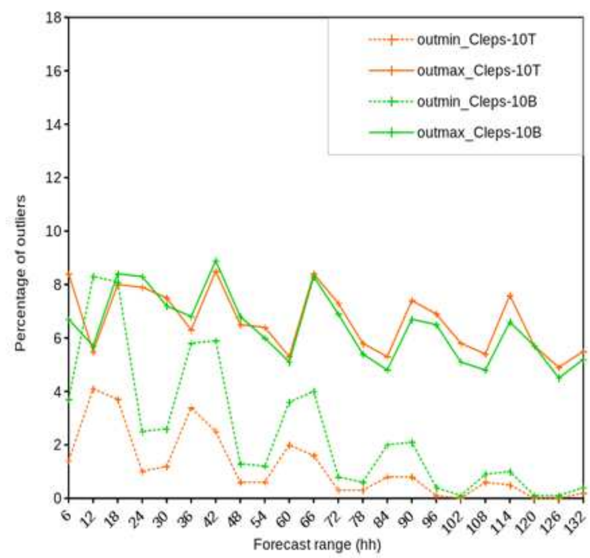


Figure 5: Left panel: Percentage of outliers for different forecast ranges in Cleps-10T and Cleps-10B (orange and green line respectively). Right panel: Percentage of outliers above/-below maximum/minimum predicted values

4 Performance of Cleps20bt and comparison with that of COSMO-LEPS

A quantitative evaluation of Cleps20bt skill in terms of precipitation forecast over the the same period is then presented. The basic idea of this study is that ensemble systems which are run using either convection schemes can describe a larger variety of uncertainty and errors in precipitation prediction (Vasconi, 2017). Thus the implementation of ensemble systems in which the two schemes are "mixed" seems to be a reasonable issue to deal with uncertanties due to the ambiguity linked to the use of a scheme or the other. It is worth pointing out that the implementation of this experimental system is consistent only because the average skill of the model when it is run in ensemble mode with the Bechtold scheme turned out to be roughly indistinguishable, from a statistical point of view, from that provided by running the model with the Tiedtke scheme, as shown in the previous Section. In fact, in a well-constructed ensemble, the skill of each individual member, averaged over a large number of events, should be approximately identical not to introduced biases and/or systematic errors in the ensemble members distribution.

The forecast skill in terms of precipitation of Cleps20bt is then assessed and compared to that of COSMO-LEPS. The main results of this study are presented in the following plots.

In Fig. 6 BSS (Brier Skill Score) is presented for different forecast ranges by considering several thresholds. In particular the focus is on the same threshold as for the 10-member case, for which a relative large number of events has been reported (1 mm/6-h and 15 mm/6-h). In order to provide an overall description of the model system performance for the different precipitation thresholds, the values reported in the plot are obtained, once again, by computing the running mean of the 6-h precipitation forecast skill over 24 hours. The plot shows that Cleps20bt has higher values of BSS than COSMO-LEPS for the thresholds reported, especially for forecast ranges from 42 hours onwards (blue and red lines respectively).

In addition to this, the RPSS (Ranked Probability Skill Score) of this system has been computed for different forecast ranges and compared to that of COSMO-LEPS during the same period. The comparison between the 24-h running mean of RPSS for the two systems is presented in Fig. 7. Also in this case a better performance of Cleps20bt than that of COSMO-LEPS is evident for forecast ranges from 2 days onwards: for example RPSS in the forecast range +60-66 hours is about 5% higher in Cleps20bt than in COSMO-LEPS; it is about 10% higher in the new system for +90-96 h, +96-102 h ranges.

A similar behaviour can be detectable also in other scores (Brier Score and ROC Area), which are not presented here.

Finally the performance of the systems is evaluated in terms of the percentage of outliers (left panel in Fig. 8). In addition to this, similarly to the 10-member ensembles case, the percentage of outliers are discriminated between the fractions of points in which observed values lay outside the forecast range over the full verification

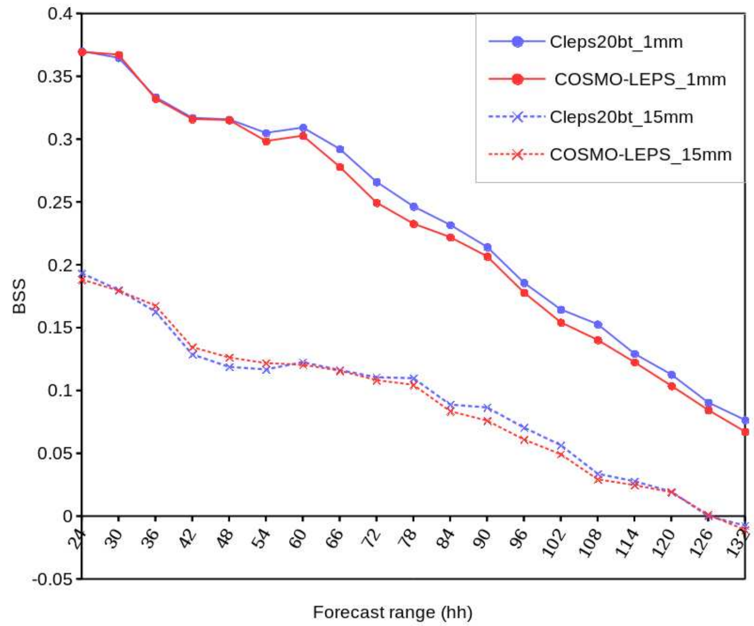


Figure 6: 24-h running mean of BSS values for 6-h accumulated precipitation exceeding 1 mm and 15 mm (solid and dashed line respectively) for different forecast ranges in COSMO-LEPS (red line) and Cleps20bt (blue line).

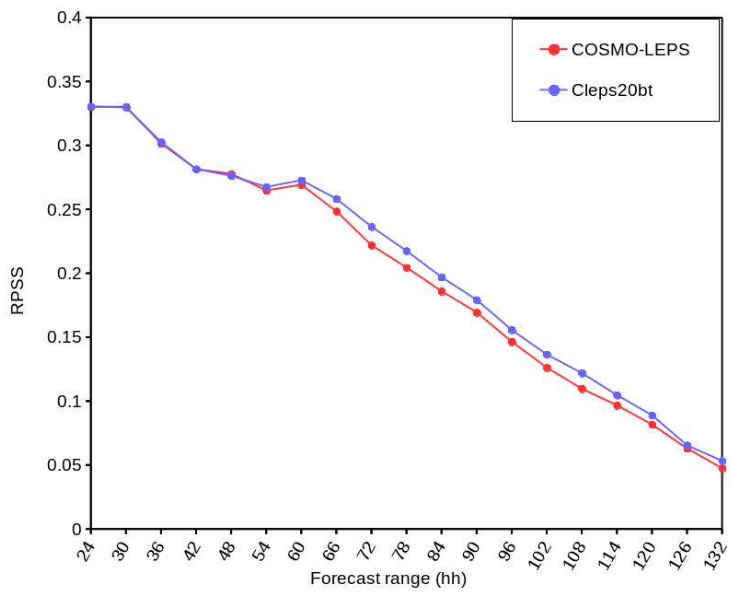


Figure 7: 24-h running mean of RPSS values for 6-h accumulated precipitation for different forecast ranges in COSMO-LEPS (red line) and Cleps20bt (blue line).

period (right panel in Fig. 8). The percentage of outliers is reduced in Cleps20bt over most of the forecast ranges with respect to COSMO-LEPS, especially from 3 days (+72 hours) onwards.

The right panel in Fig. 8 shows that the total percentage of outliers is reduced in Cleps20bt as a consequence of a decrease in the number of points wherethe total precipitation maxima are underestimated compared to COSMO-LEPS. In fact the fraction of observations found above the maximum forecast value is lower in Cleps20bt than in COSMO-LEPS, for most of forecast ranges, especially in the medium range (from +72 hours onwards). This is a quite encouraging result because Cleps-20bt turns out to perform better than the operational COSMO-LEPS in forecasting the possible peaks in cumulated precipitation over the 2-month period. It is worth underlining that the probabilistic forecast of these values is one of the most important issue of operational systems, because it regards the correct prediction of heavy rainfall events, which may

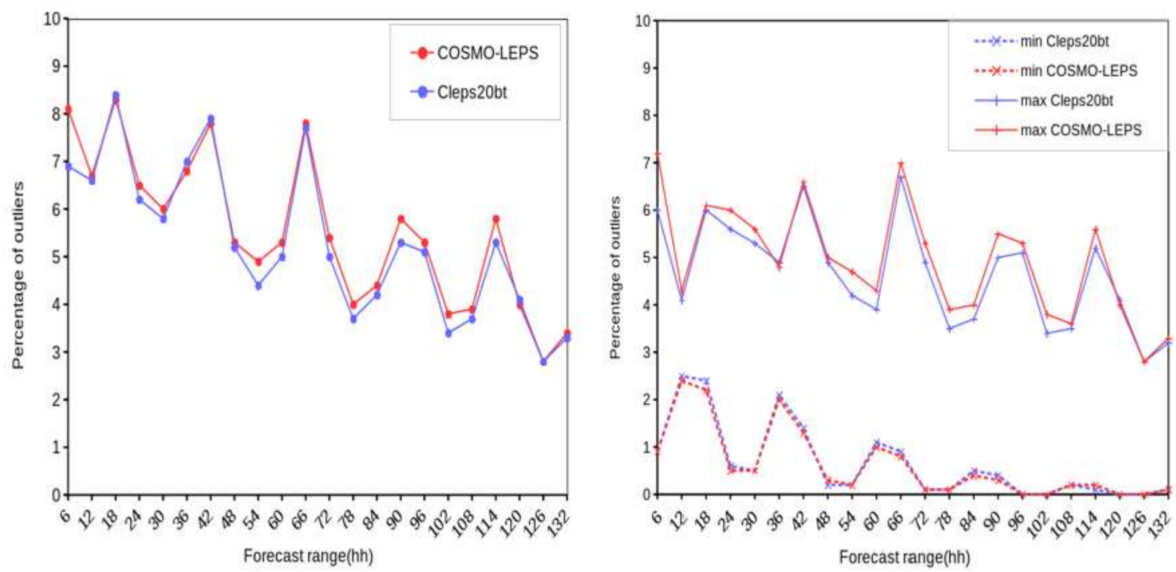


Figure 8: Left panel: Percentage of outliers for different forecast ranges in COSMO-LEPS (red line) and Cleps20bt (blue line). Right panel: Percentage of outliers above/below maximum/minimum predicted values.

have a high impact on the society.

This result, together with those presented in this section, substantially agrees with the idea that, by adding a physical perturbation to the system (like what we have done in this work using an ensemble system in which two different moist convective schemes are used), we can obtain a more appropriate description of the phase-space of all possible future atmospheric states which are compatible with the uncertain model formulation of the moist convection sub-grid processes. Thus, according to this experimentation, the generation of a multi-physics ensemble system provides a positive impact on the forecast capability at high resolution. This is especially true in early-medium range, when model errors start playing an important role and it is crucial for an ensemble system to provide an accurate description of the different sources of forecast deficiency (Vasconi, 2017).

4 Summary and Outlook

The impact of the use of two moist convection schemes (the Tiedtke and Bechtold schemes) has been studied in ensemble mode. Firstly a 10-member ensemble with the Becthtold scheme (Cleps-10B), which uses the same initial and boundary conditions as members 1-10 of the operational COSMO-LEPS, has been run has been run for approximately 2 months. The performance of these members has been assessed and compared again to that of Cleps-10T, the 10-member ensemble made of members 1-10 of COSMO-LEPS; in particular the spread/skill relation of the two 10-member ensemble in terms of total precipitation is evaluated. Verification has been performed for precipitation events occurred over Northern Italy (using the forecast at the gridpoints nearest to about 1000 stations) from 28th March to 31th May 2017. The average skill of the Cleps-10B runs turned out to be substantially indistinguishable, from a statistical point of view, from that provided by the Cleps-10T ones. However a deeper analysis suggests that the two ensemble systems are characterised by different types of forecast errors. Therefore a new 20-member ensemble system (Cleps20bt, which has 10 members run with Bechtold plus 10 members run with Tiedtke and no duplication of boundary conditions) has been implemented. In this system the Bechtold scheme is used as a perturbation for the COSMO-LEPS ensemble, so as to provide a quantitative description of uncertainties linked to the model representation of the cumulus convection. Cleps20bt has been shown to have higher skill than COSMO-LEPS over the verification period. In addition to this, the comparison of the Percentage of Outliers in the two systems shows a reduction in the fraction of observed points lying outside the maximum or minimum forecast value in Cleps20bt. These results suggest that the use of a probabilistic system in which a multiple moist convection formulation is used, provides the opportunity to have a more comprehensive description of the uncertainties in total precipitation forecast linked to the sub-grid cumulus representation.

However, further work is necessary on this topic. Firstly the sensitivity of model forecast skill in terms of other variables (2-m temperature, humidity, 10m- wind speed) has to be assessed. In fact the use of different schemes is expected to have a great impact also on these variables at high resolution scales. In addition to this, we plan to perform runs in ensemble mode for other seasons and at 5 km of horizontal resolution.

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Comparison and verification of different convection schemes in COSMO model

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1 Introduction

The horizontal resolution of the current operational prediction models is not sufficient to fully resolve convection processes, so different parameterizations have been developed. In the operational COSMO model a mass-flux scheme developed by Tiedtke [1] and based on moisture convergence closure is implemented. Recently another mass-flux scheme has been implemented in COSMO, the Bechtold scheme [2], which is based on CAPE closure and is already adopted in the operational ECMWF-IFS model. Since the parameterization of convection in limited-area models is an important source of uncertainty as regards the spatio-temporal forecast of precipitation, different runs have been performed in the framework of the COSMO Priority Task CIAO (implementation of the Bechtold Convection scheme In the model: deterministic And ensemble-mOde tests) to evaluate the performance of the different convection schemes on the forecast skill.

2 Model set-up and methodology

The operational Tiedtke and the Bechtold convection schemes have been tested over an integration domain covering Italy at the horizontal resolution of about 5 and 7 km (COSMO-I5 and COSMO-I7 respectively). Three case studies have been chosen among various recent events of heavy precipitation and intense convective processes, two in summer that occurred over Piedmont on May 2017 and over Tuscany on September 2017 and one very unusual in winter that occurred over Piedmont on January 2018. Different methods have been used for verifying spatial forecast of precipitation and comparing the model output obtained by the two convection schemes. First a qualitative evaluation has been carried out by visually comparing forecast and observation maps of precipitation, then a quantitative approach has been applied, called the neighborhood (fuzzy) verification method. The fuzzy verification method [5, 6] is a new spatial verification technique which does not require an exact match between forecast and observation. This multi scale-intensity approach returns the traditional model skills according to different precipitation intensities and spatial scales. In this way it can be determined how the forecast skill varies with neighborhood size and which is the smallest neighborhood size that provides a sufficiently skillful forecast in order to answer the question: "What are the spatial scales at which the forecast resembles the observations?" As suggested by Robert et al.[3] the Fractional Skill Score (FSS), which compares the forecast and observed fractional coverage of grid-box events in spatial windows of increasing size, has been used. The skillful spatial scale is L, calculated according to the value of FSS (FSS $> 0.5 + f/2$), where f is the observed fractional rainfall coverage over the domain or wet-area ratio. This represents a lower limit of useful scales. If f is not very large, and it typically is not for a large domain, a value of 0.5 can be used as a lower limit, whereas higher value has to be adopted for higher wet-area ratio. Precipitation forecast maps, referred to COSMO-T for Tiedtke convection scheme and COSMO-B for Bechtold convection scheme, have been compared with the precipitation maps estimated by the radar composite of the Department of Civil Protection. In figure 1 the computational domain, the verification domains over Italy and over Piedmont (red line, I-domain, and black line, P-domain, respectively) and the radar composite of the Department of Civil Protection (red area) are shown.

3 Results and verification

Concerning the heavy rain event occurred on May 18-19 2017 over Piedmont, the 48 hours total precipitation forecast maps are visually compared with observed precipitation map estimated by the radar composite of the Department of Civil Protection in figure 2. Only simulations performed by using the two described convection schemes with a resolution of 5 km are shown, since results regarding 7 km resolution did not change significantly. Both the simulations with different schemes represent quite well the total precipitation observed during the event, even if the heavy rain over the Cuneo area (Southwestern Piedmont) was completely missed. Further the Bechtold scheme seems to smooth peak values with respect to operational Tiedtke scheme.

In order to carry on a quantitative analysis of the results, the fuzzy verification has been applied to two different domains, one covering the overall Italy (I-domain) and the other covering the Piedmont (P-domain), which includes the most rainfall coverage and is indeed characterized by a high wet-area ratio. The FSS maps are shown in figure 3 and they point out that the Tiedtke scheme has a slightly better overall behavior than Bechtold scheme, even if the useful scale (number in bold) has no improvement. The useful scale has some improvement in the smaller verification domain, since it is included only the event of interest and the unrelated rainy areas far away are excluded, although for 3-hourly precipitation rate higher than 2 mm there is no useful scale L on those investigated (less or equal to 170 km).

The same methodology of evaluation has been applied to the heavy rain event occurred on September 10 2017 over Tuscany. The daily precipitation forecast maps at 5 km resolution are visually compared with observed precipitation map in figure 4. Unlike the previous event which interested mainly the Piedmont, this event involved the entire peninsula and the observed rainfall area covered large part of the verification domain. The simulations with the two different convection schemes are quite similar, though the Bechtold scheme seems to smooth peak values of precipitation compared to Tiedtke scheme. High precipitation rates have been quite well forecast over Tuscany and Lazio, while they have been clearly overestimated over Northern Italy.

In figure 5 the fuzzy verification calculated over the Italy domain is shown for the different convection schemes and points out that the Tiedtke scheme has a better performance than the Bechtold one. The useful scales (L) for 3-hours rainfall accumulation of 5 mm and 2 mm are 170 km and 30 km for COSMO-T respectively, while COSMO-B has no usefule scale for the 5 mm threshold and for 2 mm L is 90 km.

The last event of heavy precipitation to be analyzed is the one occurred over Northwestern Italy on January 7-8 2018 and characterized by some convective processes such as thunderstorm and lightings, very unusually in winter. It differs from the others since precipitation was due to advective and convective processes and furthermore occurred in different forms, rain and snow. In figure 6 the 48 hours total precipitation forecast maps are visually compared with observed precipitation map provided by the Department of Civil Protection. It can be noticed a very good agreement between simulations and measurements and Bechtold scheme seems to behave better than Tiedtke scheme. The best performance compared to the other events is due to the fact that this event was mainly characterized by advective-stratiform precipitation processes, more easily to forecast. Conversely the convective processes occurring over a wide range of spatial and temporal scales, some of which are poorly understood and not always adequately parameterized, are inherently difficult to locate in space and time correctly. In order to quantitatively evaluate the model performance, the fuzzy verification

has been calculated for the two different convection schemes over the Italy domain and the Piedmont domain, which includes the most of the event, and the results shown in figure 7 point out that both schemes have a remarkable behavior. The useful scales L calculated over the I-domain for 3-hours rainfall accumulation of 10

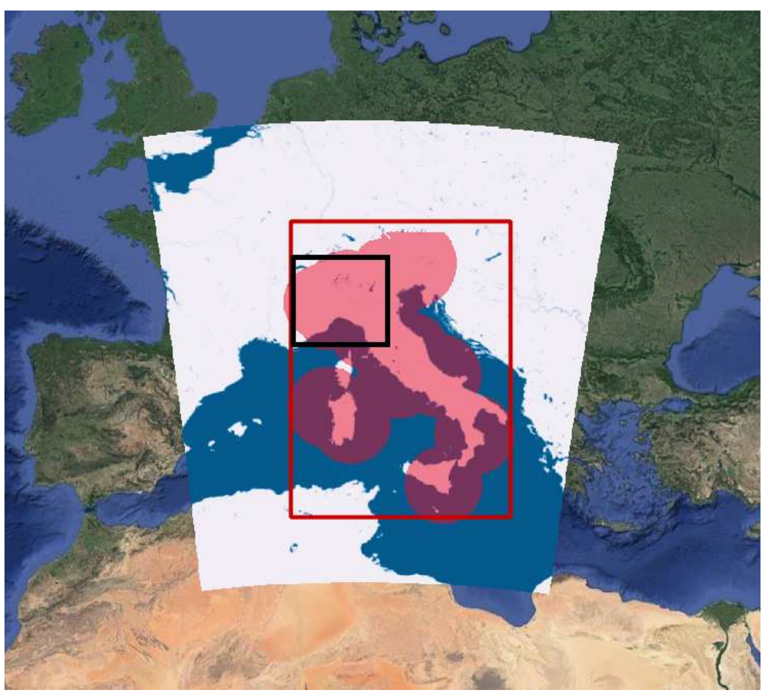

Figure 1: Computational domain, verification domain over Italy (I-domain, red line), verification domain over Piedmont (P-domain, black line) and radar composite of the Department of Civil Protection (red area).

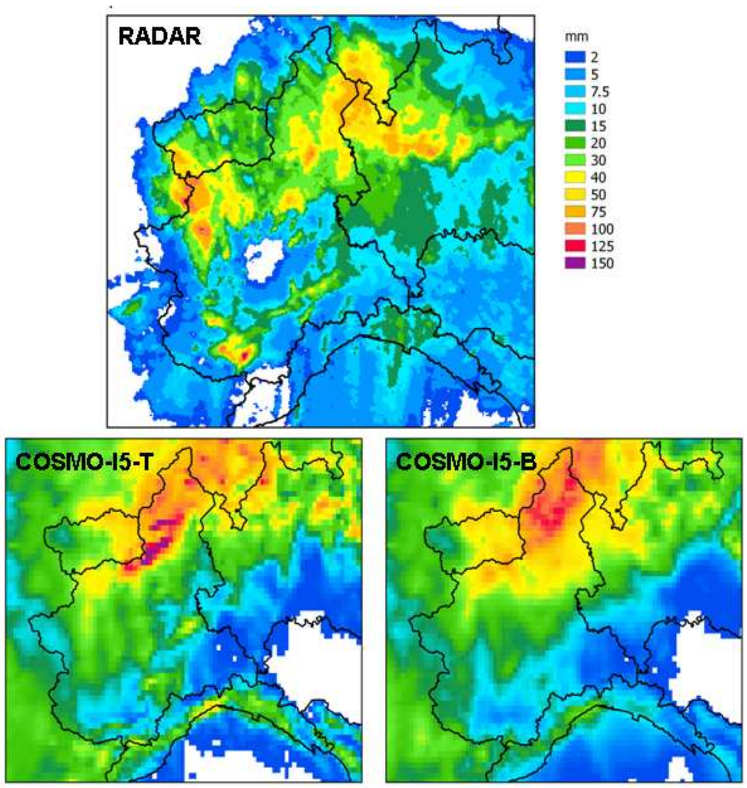

Figure 2: 48 hour total precipitation maps over Piedmont on May 18-19 2017.

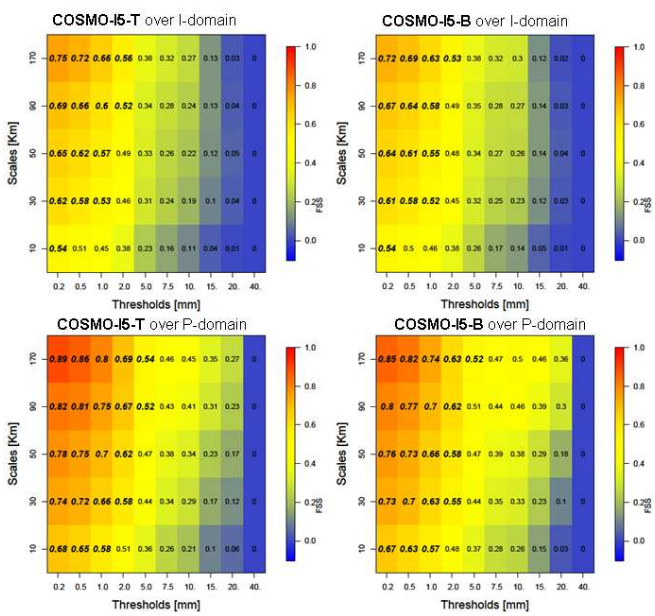

Figure 3: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of May 2017

mm are 30 km for both schemes, while for 20 mm Bechtold has a useful scale equal to 170 km and Tiedtke has no useful scale. Fss values and useful scales have further improvement in the smaller verification domain, where the unrelated rain areas are excluded: for 3-hours precipitation rates equal to 10 mm and 20 mm the useful scales are respectively 10 km and 30 km. Bechtold seems to be slightly better than Tiedtke except for very high precipitation rates, as pointed out in figure 8 which represents the difference between the FSS (T)

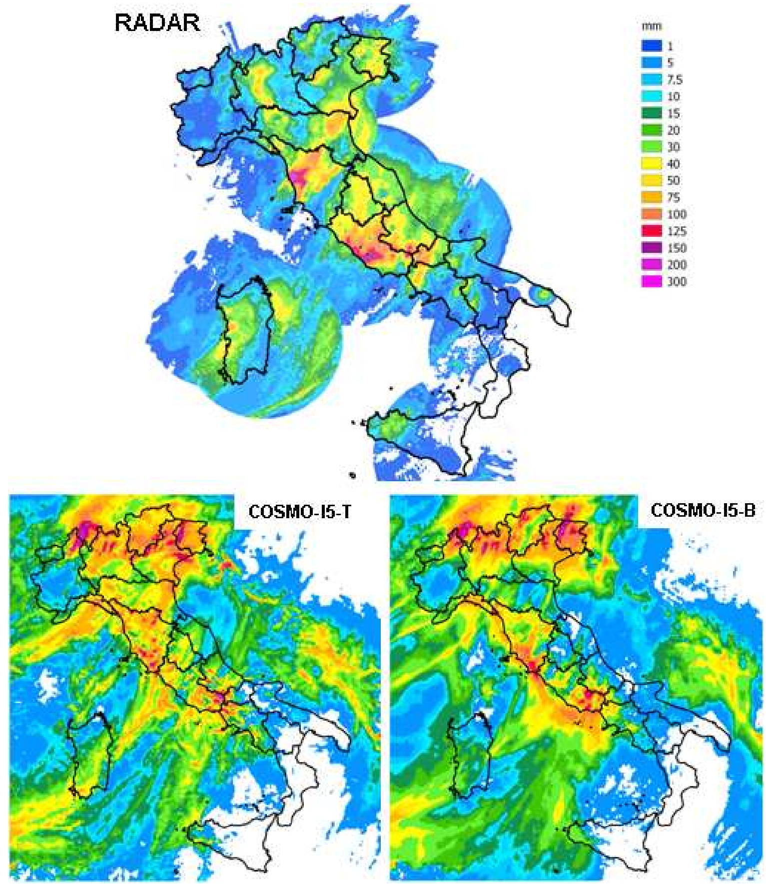

Figure 4: Daily precipitation maps over Italy on September 9 2017.

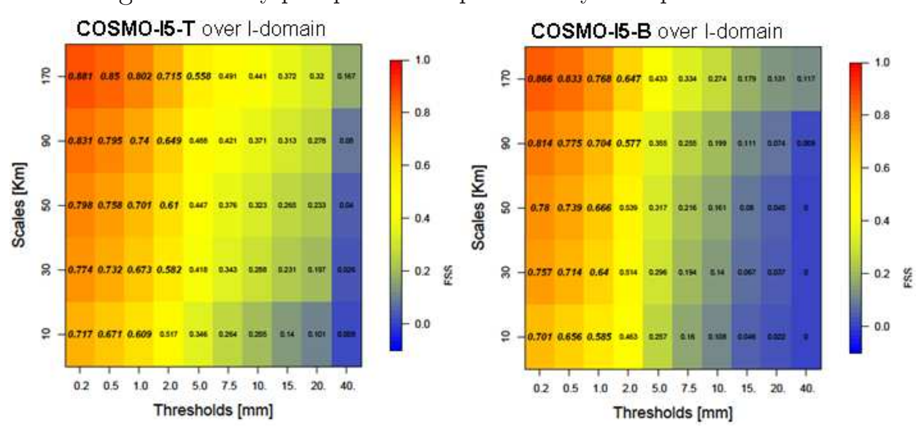

Figure 5: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of September 2017

and FSS (B) at different scales and precipitation intensity: red colors mean that the Tiedtke scheme behaves worse than Bechtold, while blue colors mean the opposite.

4 Conclusions

The comparison of precipitation between forecast maps and radar maps provided by the Department of Civil Protection points out that both schemes have a quite good performance in term of FSS regarding low precipitation intensities, while it degrades by increasing the intensity. The best values concern the verification over the domain which delimits the rain event, since the fuzzy method can be misleading in the case of a lot domain area not covered by precipitation, as shown in literature [3, 4]. The Tiedtke scheme shows a slightly

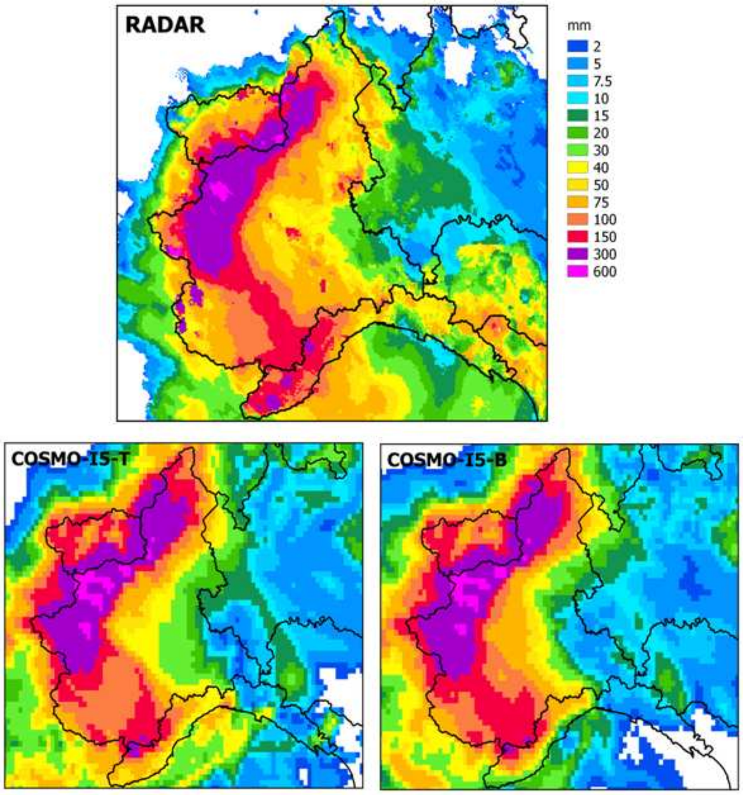

Figure 6: Total precipitation maps over Italy on 8-9th January 2018

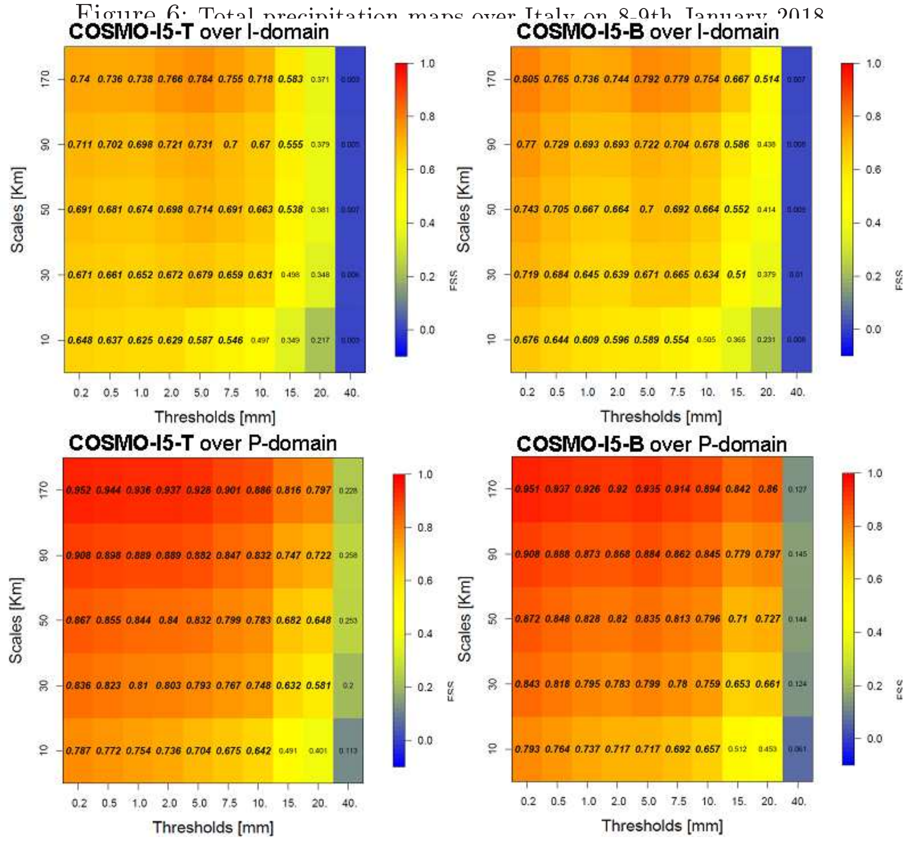

Figure 7: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of January 2018

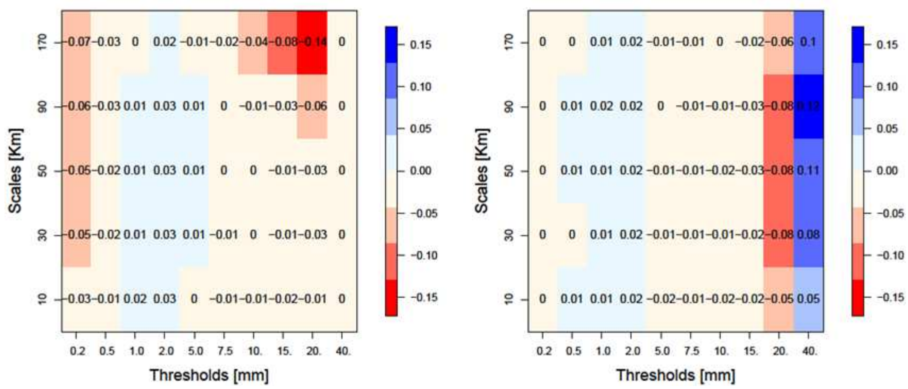

Figure 8: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of January 2018

enhanced behavior with respect to Bechtold in the summer cases, when only convective processes happen. The skill scores of both schemes remain quite unsatisfactory for high precipitation rates, where there is no useful scale over those investigated ($<$ 170 km), that means that models have not been able to locate convective heavy rain events in time and space accurately. Conversely in the winter case, when precipitation is mainly due to advective processes, FSS values are very good and useful scales achieve 10 km. Furthermore the Bechtold scheme behaves better than Tiedtke, except for very high precipitation intensity, since the Bechtold scheme seems to smooth peak values anyhow.

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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,

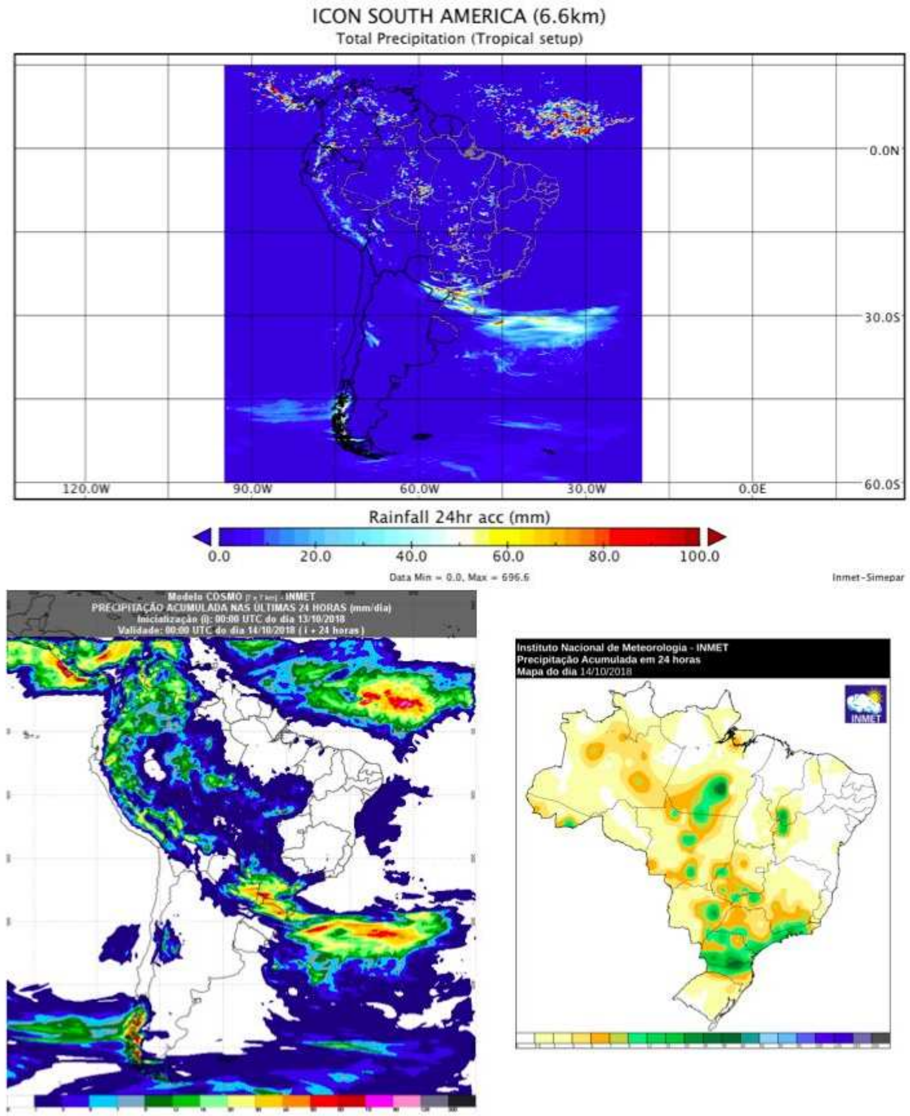

Figure 1: Comparison of the 24 h accumulated precipitation on 13 October 2018 between the Brazilian ICON 6.5 km domain (top), the operational COSMO forecast (bottom left) and measurements (bottom right). Please note the different color scales, i.e., very low values for ICON are in blue and for the other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

- Run ICON with tropical setup and without tropical setup, using icon global lateral boundaries,
- Generate output and vizualization, 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 Piaui 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

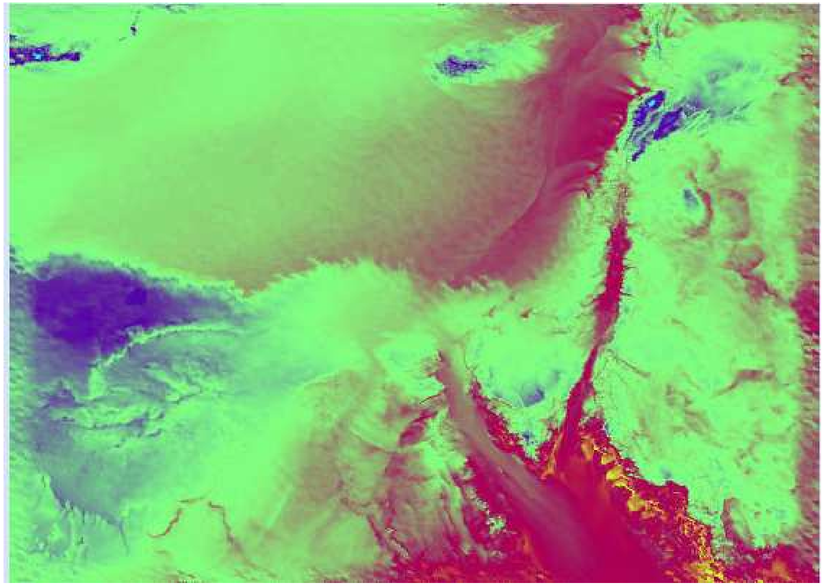

Figure 2: First results for the Israeli 3 km domain on 1 October 2018 with initial and boundary conditions from IFS.

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 T^2RC^2),
- 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 instutions 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 ICONTOOLS & ICON on CINECA HPC, and
- Run iconremap on CINECA HPC.

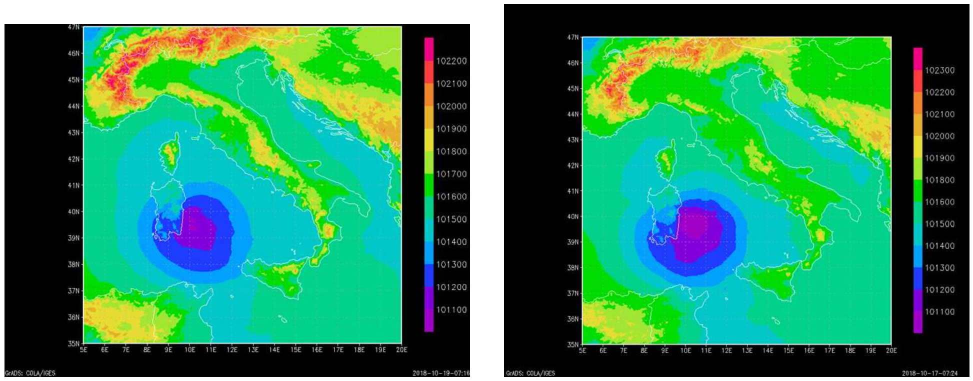

Figure 3: Mean sea level pressure on 21 September 2018, 3 UTC, for the ARPAE-SIMC domain at 2.5 km. Initial and boundary data are derived from global ICON forecast (left) and IFS forecast (right). Please note the slightly different color scales.

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.

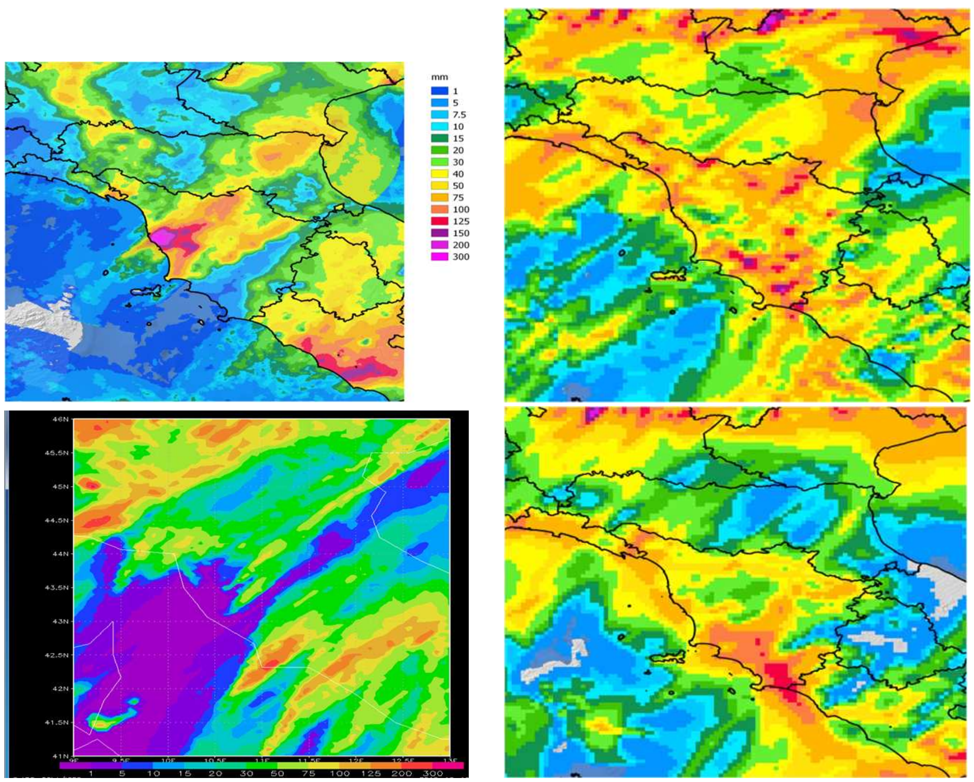

Figure 4: Accumulated precipitation in the Emilia Romagna and Tuscany region on 14 September 2017 from radar measurements (top left), ICON 5 km (bottom left), COSMO-I5 Tiedtke (top right) and COSMO-I5 Bechtold (bottom right). Please note the different color scales!

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.

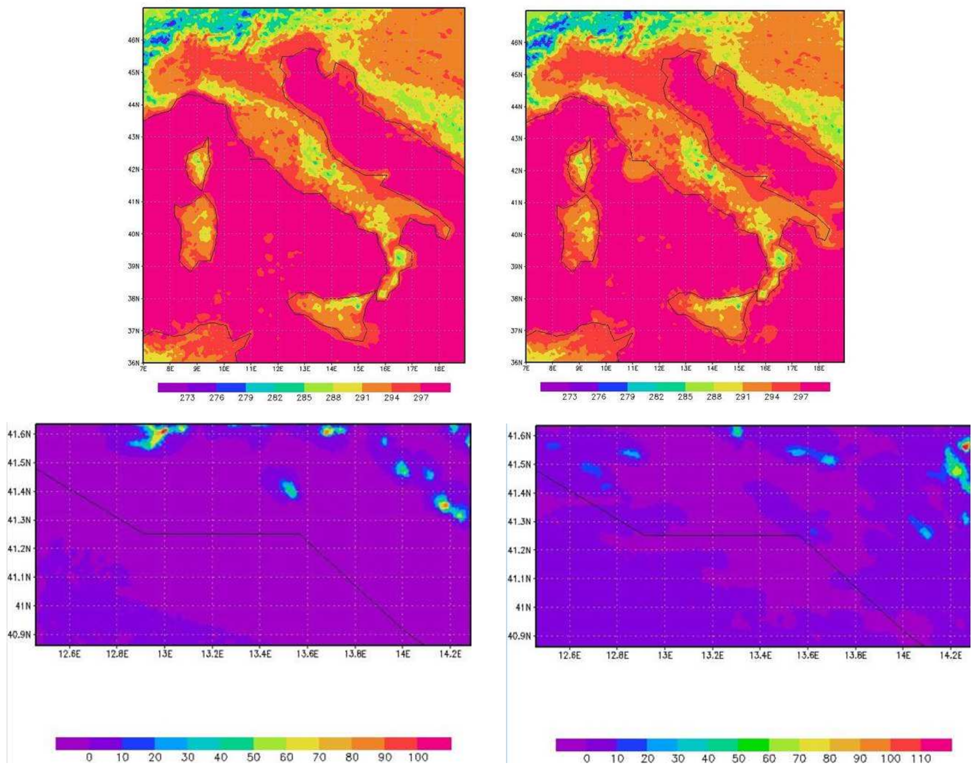

Figure 5: Results for the 2 m temperature on 21 September 2018, 21 UTC, from a simulation over the whole Italian area at 7 km, driven by ICON (top left) or IFS (top right). Total precipitation for the high-resolution domain driven with ICON initial and boundary conditions (bottom left) and IFS initial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

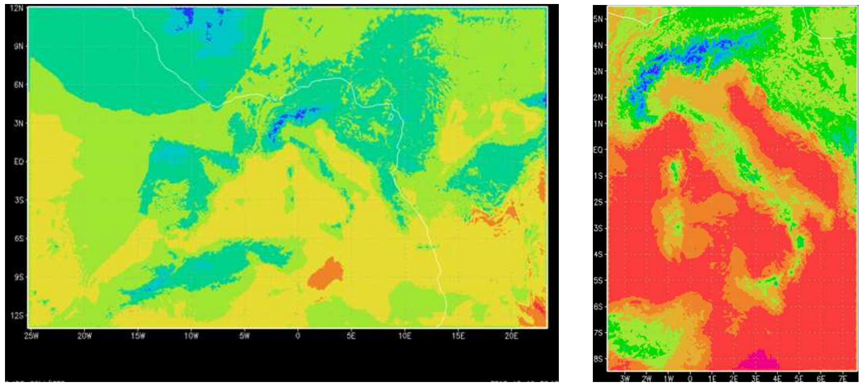

Figure 6: Results for the ICON-ME domain at 5 km (left) and the high-resolution ICON-IT domain at 2 km (right). The simulations of 21 September 2018 were driven by IFS data.

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 adaptions are necessary for this data to be usable as boundary data for ICON. Among the changes are the calculation of soil moisture index (SMI), adaption of pressure levels (i.e., only `z` or `phi` at surface are needed, other `z` and `phi` 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 radioation 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 simuation 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

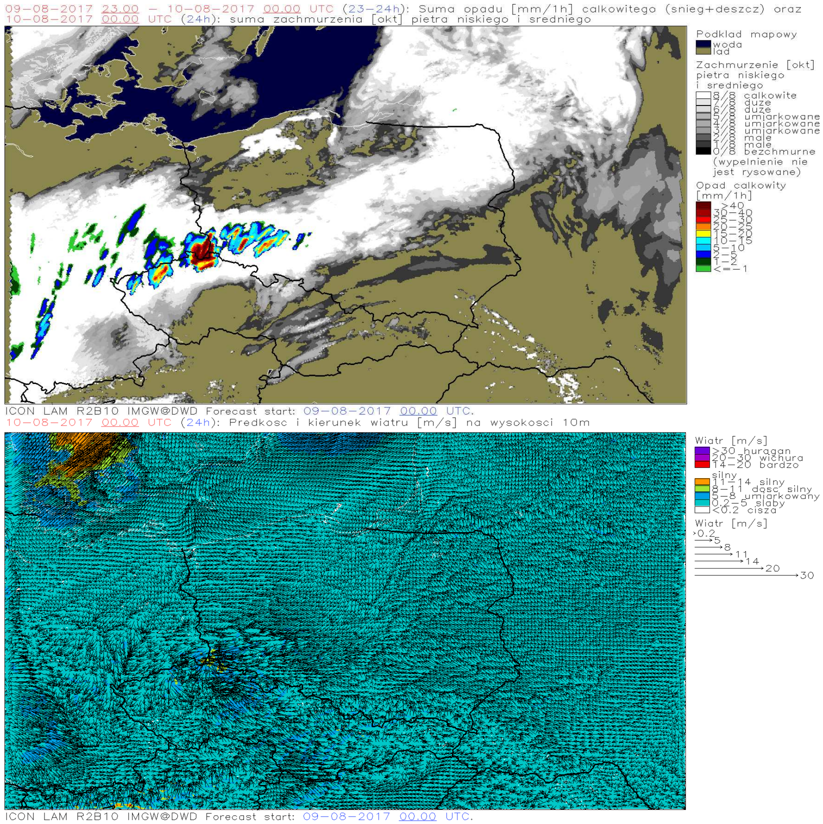

Figure 7: Total cloud cover and precipitation (top) and wind speed and direction (bottom) after 24 h of simulation on 10 August 2017, 0 UTC, for the Polish 2.5 km domain.

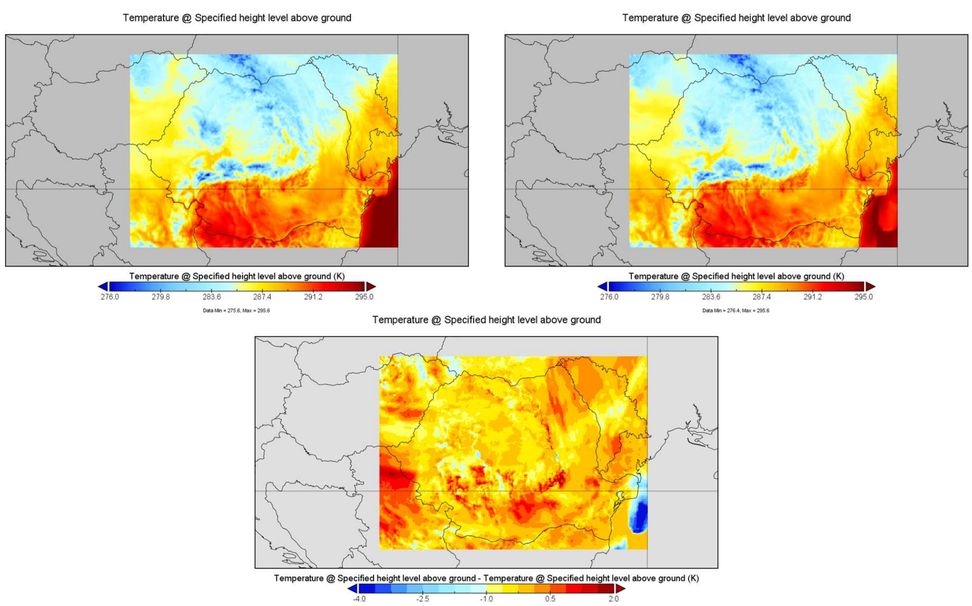

Figure 8: Results for 2 m temperature on 21 September 2018 in the Romanian (NMA) high-resolution domain. The 2.8 km simulation is directly driven by global ICON data (top left) or with an intermediate step, i.e., a 6.5 km simulation of the Romanian domain (top right). The bottom figure shows the difference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

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

7 Achievements for Russia

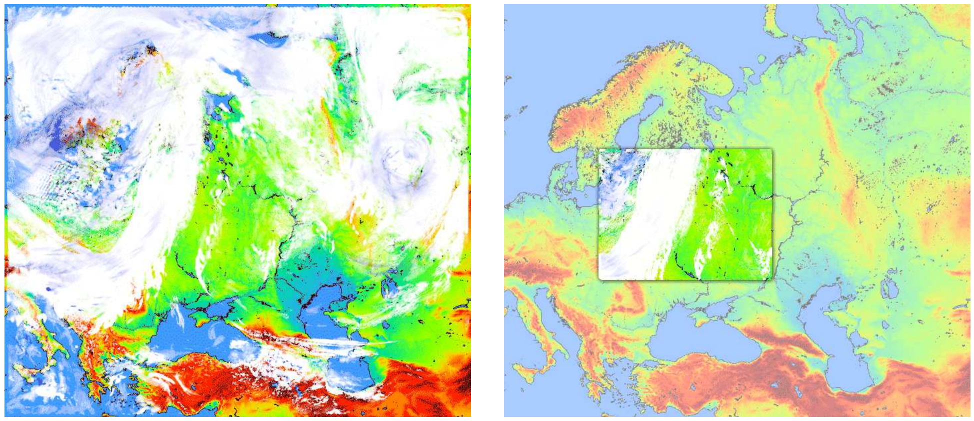

Figure 9: Total cloud cover (white) and accumulated 48 h precipitation (blue) on 21 September 2018 for the 6.5 km Russian domain (left) and the 3.2 km nested domain (right).

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.

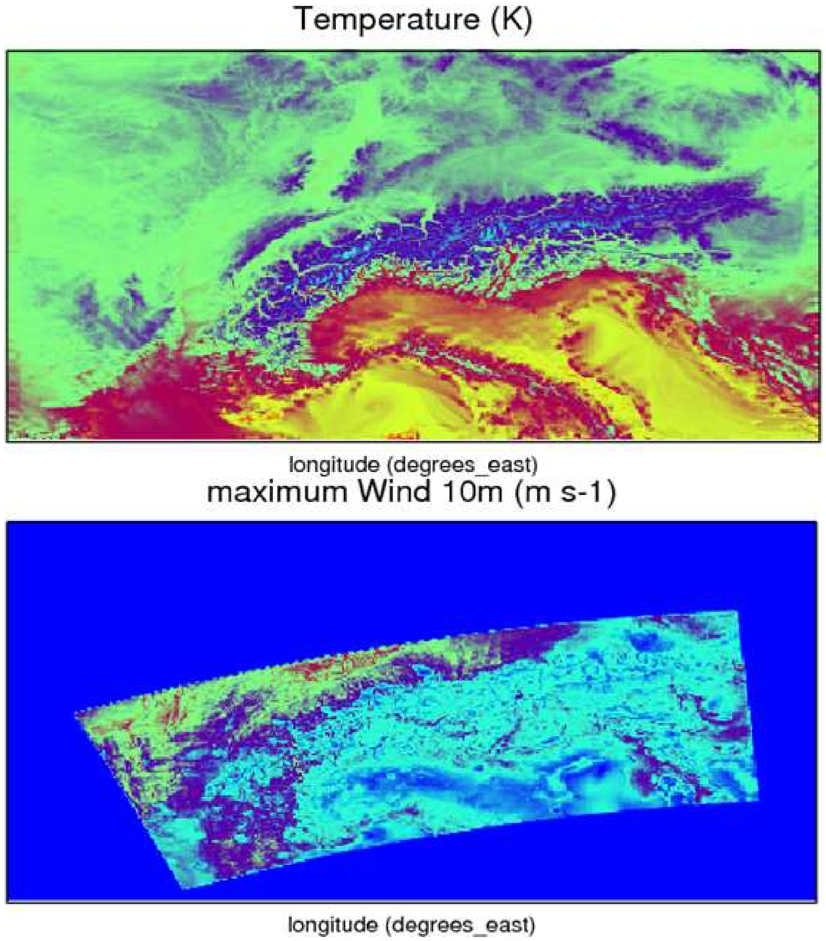

Figure 10: First results for the large Swiss 1 km domain (top) and the nested 500 m region following the arch described by the Alps (bottom).

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,

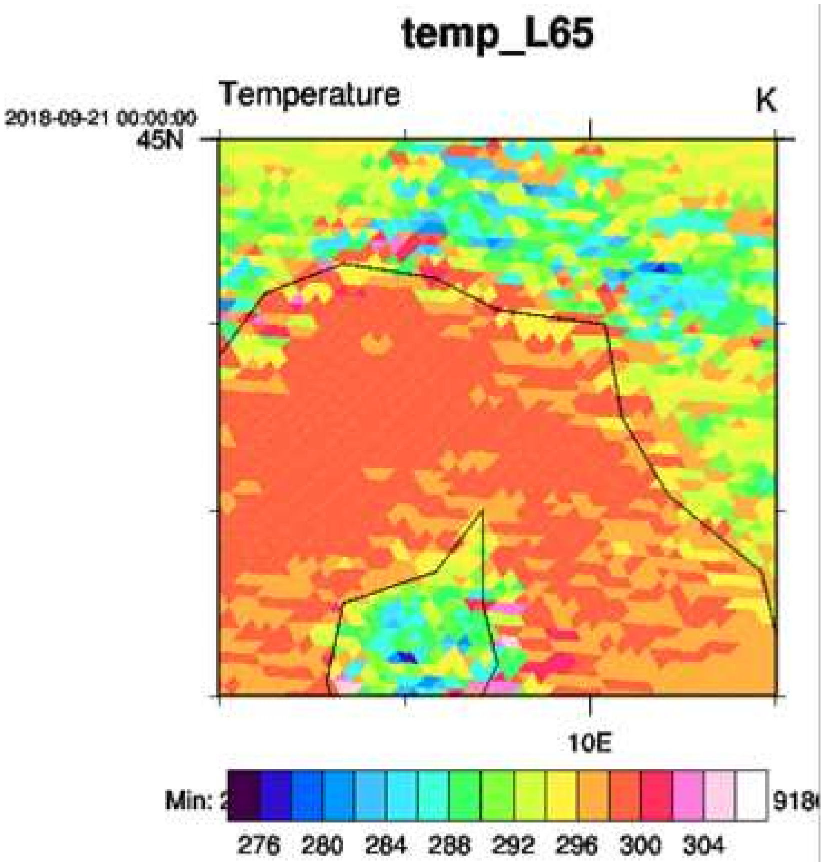

Figure 11: Example for an interpolation bug in iconremap of IFS data that many of the participants were facing. The visualization was performed with NCL on the native triangular ICON grid.

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 retrival 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.

ICCARUS 2018 - The ICON/COSMO/CLM/ART User Seminar

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1 Overview

The ICON/COSMO/CLM/ART User Seminar (ICCARUS) brings together developers and users of the COSMO-model and the ICON model from different meteorological services, universities and research institutions. With about 200 participants from 17 countries, ICCARUS is the hub for the scientific exchange between these different users and developers. Figure 1 shows a group picture of this years' participants.

Figure 1: Group picture of the ICCARUS 2018 participants.

In this year, the seminar was held for the first time under its new name ICCARUS. The new name became necessary, as users and developers of ICON joined the seminar in the year 2017. This led to the long and unhandy name ICON/COSMO/CLM/ART User Seminar. For this reason, an ideas competition was arranged where ICCARUS was suggested by eight submissions. The search for a new logo was also successful which can be seen in Figure 2.

The program contained 112 contributions in total. 44 of these were presented as oral speeches and 68 in form of a poster. The contributions were organized within 10 different sessions. The sessions are 'Data Assimilation', 'Model Input Data', 'Dynamics and Numeric', 'Clouds, Chemistry, Aerosol and Radiation', 'Planetary Boundary Layer', 'Soil, Vegetation, and Ocean', 'Verification (NWP) and Evaluation (RCM)', 'Predictability and Ensemble Systems', 'NWP Model Applications and Case Studies' and 'RCM Model Applications'. Figure 3 shows a picture of the opening of the seminar held by the president of DWD, Prof. Gerhard Adrian (Figure 3). Then, Prof. Sarah Jones, the head of the DWD Business Area Research and Development, welcomed the participants of the seminar and summarized recent achievements and advances at DWD.

2 Scientific Highlights

Certainly, the invited talks supported by COSMO turned out to be two of the highlights of ICCARUS 2018. Prof. Robin Hogan from ECMWF (European Centre for Medium-Range Weather Forecasts, Reading) provided an overview on radiation in NWP. He focussed on recent advances and the five 'grand challenges'

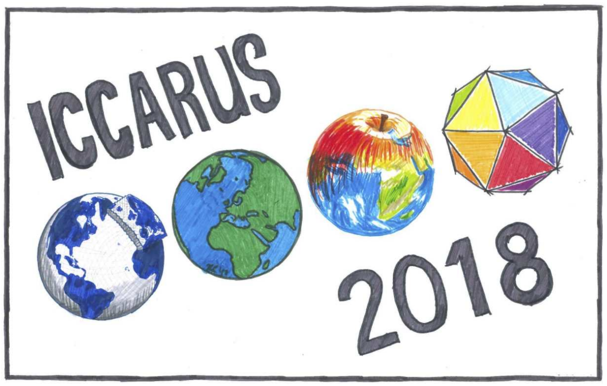

Figure 2: The new logo for ICCARUS designed by Nora Leps (Goethe-Universität Frankfurt, Deutscher Wetterdienst).

Figure 3: The president of Deutscher Wetterdienst, Prof. Gerhard Adrian, opens the ICCARUS 2018.

in the future. These are the surface, clouds, clear-sky absorption, the middle atmosphere and efficiency. The SPARTACUS (Speedy Algorithm for Radiative Transfer through Cloud Sides, [1]) solver to account for complex 3-D surfaces was introduced and the benefits were shown in applications to forests and urban areas. The same solver was also used to account for 3-D effects of clouds leading to, for example, improved solar power forecasts. For clear-sky cases, the improvements in forecasting Indian monsoon rainfall by using recent aerosol estimates were pointed out. A large stratospheric temperature bias during the polar winter has been persistent in the IFS model for at least 25 years. Removing this temperature bias in an experiment with an artificial reduction of water vapor significantly increased the overall forecast quality. In terms of computational efficiency, radiation in global models is typically used at a decreased spatial, temporal or spectral resolution or a combination of these. An assessment of the current state in the IFS model showed that the balance should be shifted towards an increased temporal resolution.

The second invited talk was held by Dr. Martin Losch from AWI (Alfred Wegener Institute, Bremerhaven). The presentation stressed the importance of high resolution in sea ice modelling. After introducing the concept of viscous-plastic sea ice models, impressive visualizations of high-resolution horizontal sea-ice distributions were shown. From comparisons with satellite measurements, it was clearly visible that the spatial scaling properties are reproduced well. However, the number of deformation events is too low in models. To stress the importance of accurate sea ice modelling, Dr. Losch focussed on land fast ice in the second half of his talk. This is the term for ice that is fastened to the shore lines and is not moving. The border of land fast ice plays a significant role as polynyas can develop there. These polynyas are important for energy transfer, the mixing of water layers and salinity. Although the solutions do not converge, the results of high-resolution models are more realistic. Thus, this further highlights the importance of high resolution sea ice modelling especially for coupled models.

Besides the invited talks, there are traditionally overview talks concerning each of the different models and communities involved in ICCARUS. Dr. Ulrich Schättler from DWD could present the long awaited version 5.05 of the COSMO-model. Starting with a retrospective summary, he explained the reasons for the late delivery of the COSMO-model version 5.05. After the introduction of the common COSMO-ICON physics package, the different tests showed heterogeneous results. While hindcasts showed benefits, the full data assimilation experiements performed worse with one problem being the drying out of soil. Even some crashes of ensemble members happened. This led to the decision to introduce DWDs' new setup COSMO-D2 with the old physics settings. Dr. Schättler also stressed the point, that, anyways, due to significant differences in the preprocessing of external data not all ICON physics developments could be used in COSMO. The real unification of the physics used in global and regional NWP will come along with ICON-LAM (ICON in limited-area mode).

Dr. Günther Zängl from DWD presented the plans for a transition from the COSMO-model to ICON-LAM. The basic motiviation is to establish one unified modelling system covering all the operational applications at DWD. This results in a reduction of the workload for implementing and testing model improvements. These plans include a coupling of KENDA and ICON-LAM with a first version being ready in the summer 2018. A consolidated version can be expected at the end of 2018. This marks one of the crucial steps for the operationalization of ICON-LAM, which is planned for summer 2019 in the parallel routine and finally becoming operational in the second half of 2020. As this is a sort of pioneering work with ICON-LAM, the transition plan for the other COSMO members is temporally shifted. To prepare and organize this process, Dr. Daniel Rieger from DWD initiated the COSMO priority project C2I (Transition of COSMO to ICON) that accompanies the intended joint transition of the COSMO members to ICON-LAM. Dr. Zängl then showed the results of first ICON-LAM tests in a configuration that matches closely the COSMO-D2 setup. These hindcast experiments driven by data from ICON-EU assimilation cycle cover seven different months spread over all seasons. The results were also compared to two months of COSMO-D2 reference experiments. The outcome is that ICON-D2 shows significantly better scores than COSMO-D2, in particular for variables for which the COSMO model has known weaknesses. This provides a good starting point for upcoming experiments with data assimilation cycling.

ICON is being developed in a strong collaboration between DWD and Max-Planck-Institute for Meteorology in Hamburg. For the first time, this was also reflected in the presentations at ICCARUS. Dr. Marco Giorgetta, the head of development of the atmospheric component of the ICON climate mode, presented an overview of the climate physics package and recent evaluation experiments. The most important requirements for these developments are a closed water cycle, a realistic energy budget and acceptable biases. It should also be flexible enough to cover a wide range of resolutions. The primary goals of the tuning efforts were a near-zero energy balance at the top of the model atmosphere and small errors in ocean surface stress. In summary, the tuning efforts were successful for a certain resolution providing a good representation of the mean climate and its variability. The improvements due to the tuning efforts were larger than changes that can be achieved by simply increasing the resolution without re-tuning. Circulation patterns in the middle atmosphere and the vertical distribution of clouds are challenges to be addressed in the future.

The Aerosols and Reactive Trace gases (ART) extension has a long history together with COSMO in academic as well as in operational applications. In this year, the presentation of Dr. Heike Vogel from KIT (Karlsruhe Institute of Technology) focussed on the development of ICON-ART. A large part of the parameterizations that are needed for aerosol and chemistry simulations are already implemented and successfully tested in ICON-ART. The remaining parameterizations have reached a state where first tests are being conducted. ICON-ART is already used for quasi-operational mineral dust forecasts in the framework of the PerduS project. The modelling system is also ready to be used in case of accidental releases of pollutants as well as volcanic eruptions. A particular focus was laid on the flexibility of the ICON-ART system. The complexity of the aerosol dynamics as well as of the chemical mechanism can be chosen freely. This allows for a wide range of applications with ICON-ART. This ranges, e.g., from stratospheric chemistry on climate time scales down to studies dealing with the impact of aerosol particles on radiation and clouds on weather time scales.

3 Outlook

It can be seen from the highlights of the invited and solicited talks that ICON has arrived at ICCARUS with a growing number of contributions. This of particular importance for the upcoming COSMO priority project C2I. As the next few COSMO years will be concerned with this transition to ICON used in limited area mode, ICCARUS offers a platform to bring the different communities involved in COSMO and ICON further together.

We want to thank all participants of ICCARUS 2018 for their contributions to the success of this informative and inspiring seminar. Special thanks go to the members of the organizational committee: Anja Thomas, Daniel Egerer and Bernd Kress. We also want to thank the helpers at the seminar, Heidelore Turau and Alexander Schreiner, and to Bernd Frey who is responsible for the registration website. Last but not least, we want to thank Dr. Barbara Früh and Dr. Ulrich Blahak for sharing their experience in organizing this seminar whenever needed.

With the international popularity of the COSMO- and ICON-model, ICCARUS 2018 offered a program with many outstandig scientific contributions. The diverse scope of topics ranging all the way from LES simulations to climate projections shows that the communities and models connected to ICCARUS already cover what is summarized by the term 'seamless prediction'.

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List of COSMO Newsletters and Technical Reports

(available for download from the COSMO Website: `www.cosmo-model.org`)

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No. 1: February 2001; Proceedings from the COSMO General Meeting 2000.
No. 2: February 2002; Proceedings from the COSMO General Meeting 2001.
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No.15: July 2015; Proceedings from the COSMO General Meeting 2014.
No.16: June 2016; Proceedings from the COSMO General Meeting 2015.
No.17: July 2017; Proceedings from the COSMO General Meeting 2016.
No.18: November 2018; Proceedings from the COSMO General Meeting 2017.

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No. 1: Dmitrii Mironov and Matthias Raschendorfer (2001):
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No. 2: Reinhold Schrodin and Erdmann Heise (2001):
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No. 3: Günther Doms (2001):
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No. 5: Jean-Marie Bettems (2002):
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No. 6: Heinz-Werner Bitzer and Jürgen Steppeler (2004):
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No. 7: Hans-Joachim Herzog, Almut Gassmann (2005):
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No. 9: Erdmann Heise, Bodo Ritter, Reinhold Schrodin (2006):
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No. 10: M.D. Tsyrulnikov (2007):
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No. 19: A. Montani, D. Cesari, C. Marsigli, T. Paccagnella (2010):
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No. 21: M. Baldauf (2013):
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