CONSORTIUM FOR SMALL SCALE MODELING

COSMO

COSMO NEWSLETTER

Editor: Mihaela Bogdan

Newsletter | No.24| 2025
Consortium for Small-scale Modeling
www.cosmo-model.org

Contents

EDITORIAL

As usual, close to halfway between the ICCARUS and the COSMO General Meeting, the new issue of the COSMO Newsletter is published. Following positive feedback on the new format introduced with the Newsletter No 23, we continue with the format of short and concise contributions.
This Newsletter No 24 highlights some new developments and events of the past year.

With the operationalization of ICON for numerical weather prediction (NWP) at MeteoSwiss, all active COSMO members run ICON in their daily routine. The short report about this operationalization also highlights the aspect of running an operational NWP model on Graphics Processing Units (GPU) as an important new feature in our consortium.

The support via icon-support@cosmo-model.org – as single point of contact for COSMO members and meteorological services having signed the ICON support license – is now in operational status and the number of licensees is increasing (see overview in this NL).

Along with the progress in the operational use of ICON for NWP in COSMO, which remains the core task of the consortium, the scientific cooperation of COSMO with the broader ICON community has been further intensified in recent months. This became evident, among other things, during the working group meetings at the COSMO General Meeting 2024 in Offenbach. The planning of these meetings and the execution of the related agenda involved colleagues from the ICON community. This approach aligns with the concept of actively opening up our consortium beyond COSMO-specific projects.

As a new partner of the COSMO consortium, we welcome the Meteorology and Climatology Agency 'ItaliaMeteo' as the national meteorological service of Italy (see report). We look forward to a successful collaboration in the well-established tradition of long-standing cooperation with further Italian partners.

Together with the short reports, this newsletter provides traditionally valued information about our models' performance, publications, as well as past and future events. Many thanks to all contributors to this COSMO Newsletter and to Mihaela Bogdan and Massimo Milelli of the editorial team.
Enjoy reading!

Christoph Gebhardt
COSMO Scientific Project Manager
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A step forward for the Italian partnership in COSMO

ANTONIO VOCINO, ITAF MET SERVICE - COSMO STC DELEGATE FOR ITALY AND STC CHAIR

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At the last COSMO Steering Committee meeting (55th STC meeting, 13-14 March 2025) the "ItaliaMeteo" Agency, based in Bologna, has been formally introduced to COSMO by the Italian delegate, according to the procedure for the proposal of new scientific partnerships within the consortium.

Following the endorsement by the STC to include ItaliaMeteo as COSMO "Additional Partner", the Italian partnership in COSMO gets stronger, being the Agency designated by law (Parliament Law N. 205/2017) as the National Meteorological and Climate Agency for Italy.

As of today, ItaliaMeteo collaborates with various Italian public institutions that operate in the field of meteorology. In the area of NWP, it will particularly benefit from the expertise developed over the years by the Italian members of COSMO.

Furtherly, according to its role, ItaliaMeteo Agency aims to become responsible for maintaining and developing the national NWP system based on ICON to support Italian stakeholders, particularly the National Department of Civil Protection, promoting at the same the use of the ICON model in academia and research institutions.
More details on the web site: www.agenziaitaliameteo.it/en/homepage-en

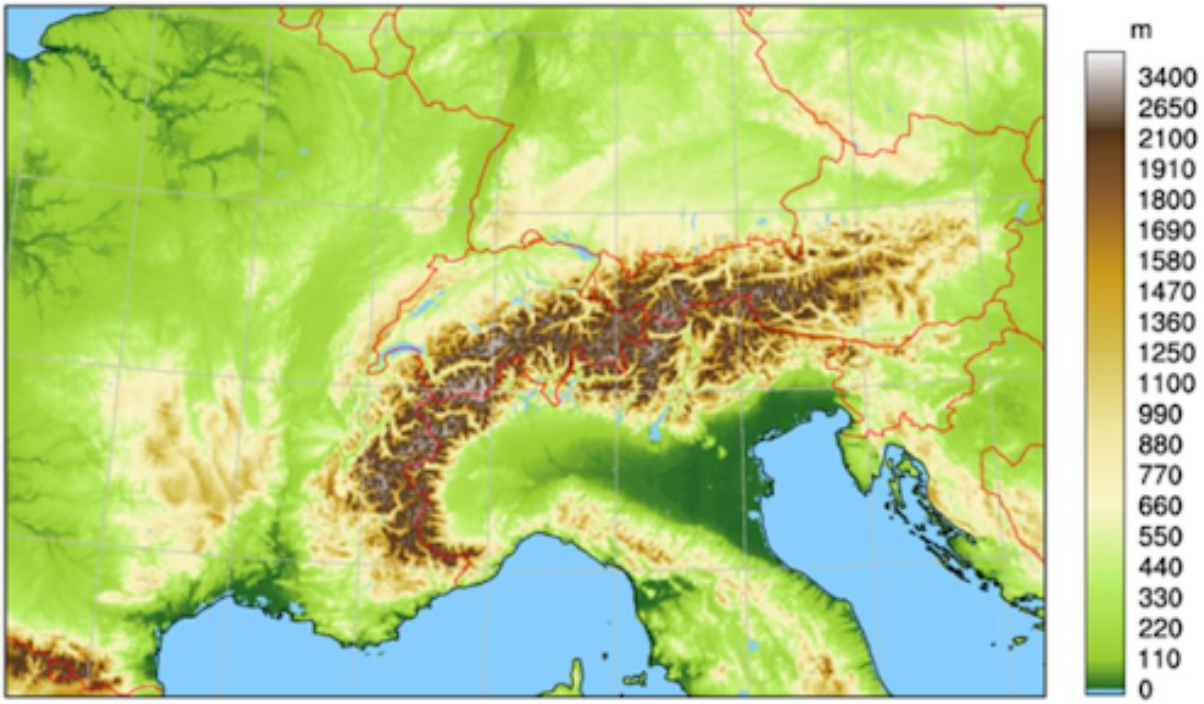
The scientific roadmap for ItaliaMeteo, as emphasized in the letter of agreement with the Italian Air Force Met Service, aligns with the ICON development through the research activities and priority projects carried out by the Working Groups within the COSMO Consortium, namely on data assimilation, physics, verification and applications, support and infrastructure, predictability and ensemble methods.

Looking at future challenges for NWP and COSMO, welcome onboard to **ItaliaMeteo**!

ICON-22 project at MeteoSwiss: Operational ICON weather forecasting on GPU

Xavier Lapillonne, Marco Arpagaus (MCH)

The ICON-22 project was successfully completed allowing MeteoSwiss to transition its operational weather prediction system from COSMO to ICON. The forecast model configurations, ICON-CH1-EPS and ICON-CH2-EPS, provide probabilistic forecasts since May 2024 at 1 km and 2 km horizontal mesh-size, respectively. The operational system is completed with the ensemble data assimilation system KENDA-CH1, also running at 1 km mesh-size. Besides the challenges associated with setting up the ICON configuration at km scale over the complex Alpine domain, the ICON model needed to be ported to GPU and is now running on the new Alps supercomputing infrastructure at the Swiss National Supercomputing Center CSCS.



Model domain for KENDA-CH1, ICON-CH1-EPS, and ICON-CH2-EPS.

ICON model performance

In general, the newly operational ICON forecasts are better quality than the old operational COSMO forecasts for all lead-times. As compared to COSMO, the forecasts of ICON typically show smaller (i.e., better) standard deviations of the error (STDE), higher (i.e., better) values for the Rank Probability Skill Score (RPSS), and lower (i.e., better) values for the Continuous Rank Probability Score (CRPS). This is an indication that ICON can better forecast the day-to-day variability of the atmosphere than COSMO. On the other hand, ICON exhibits stronger systematic model biases than COSMO for some key variables such as, e.g., temperature at 2m (too warm, most pronounced in Alpine valleys).

Work at MeteoSwiss since ICON went operational has focused on improving the shortcomings of ICON compared to COSMO. We will report on these developments at our regular consortium meetings.

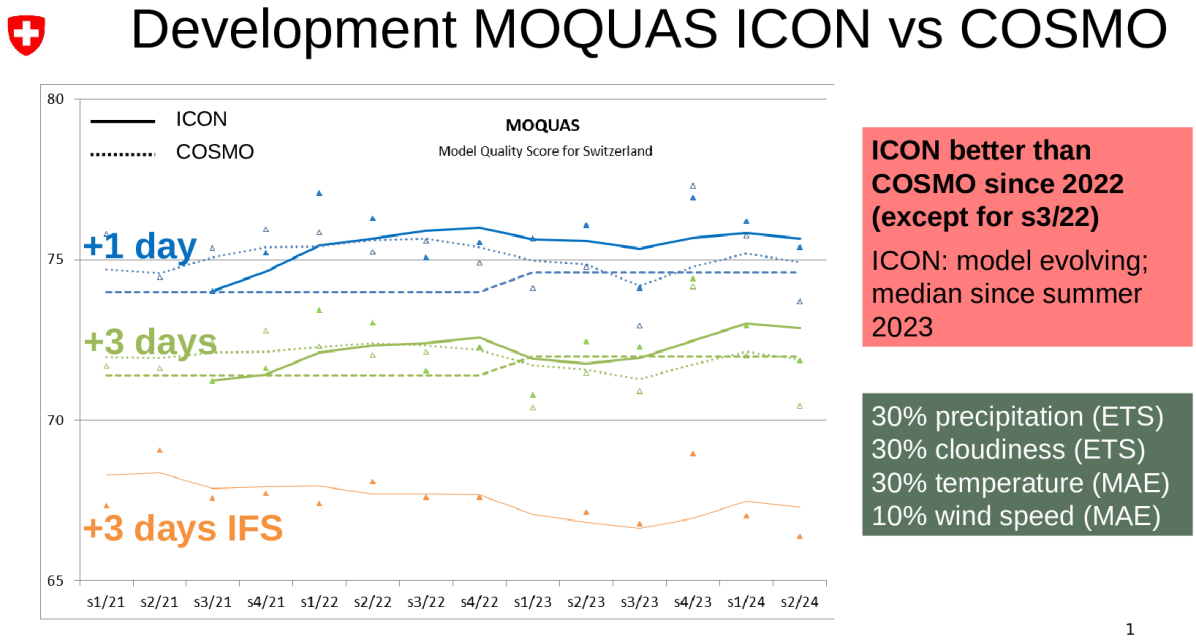


Figure: Pirmin Kaufmann

MOQUAS at the time ICON went operational at MeteoSwiss. - MOQUAS is a summary score for the model performance. It consists of partial scores for precipitation (weight 30%), cloud cover (weight 30%), temperature (weight 30%), and wind speed (weight 10%).

GPU porting

The ICON model was successfully ported to GPU using OpenACC compiler directives as part of the COSMO Priority Project IMPACT and in close collaboration with the ICON-22 project. All the changes required to run on GPU for the most used configurations, namely the DWD and MeteoSwiss operational configurations, have been merged into the main code and are now available to the wider ICON community. A strong focus of the IMPACT project was performance and the required time to solution for product delivery. For the ICON-CH1-EPS configuration the 33 h forecast needs to be completed in less than 50 min. This is achieved by using 8 A100 Nvidia GPUs resulting in a runtime of less than 45 min. A performance comparison using the same number of GPU or CPU hardware, e.g., 8 GPUs compared to 8 Multicore CPUs, shows a speed up factor of about 5x.

Computing infrastructure

Contrary to the previous dedicated installation, the new MeteoSwiss computing system is part of the larger Alps Supercomputer Infrastructure at CSCS and is implemented as a so-called versatile cluster over multiple sites. This allows for more flexibility, in particular the size of the R&D system can be adapted to the current needs. The operational cluster Tasna is running in Lausanne while the failover and R&D system is in Lugano, increasing the reliability of the full system.

In memory of André Walser

The ICON-22 project was led by our beloved colleague André Walser who passed away completely unexpectedly in February 2025. Besides ICON-22, André was the driving force behind many more developments at MeteoSwiss as well as within the COSMO community. We deeply miss him as a wonderful colleague and dear friend and will always remember his kindness, his positive view on everything, and his dedication to weather forecasting.

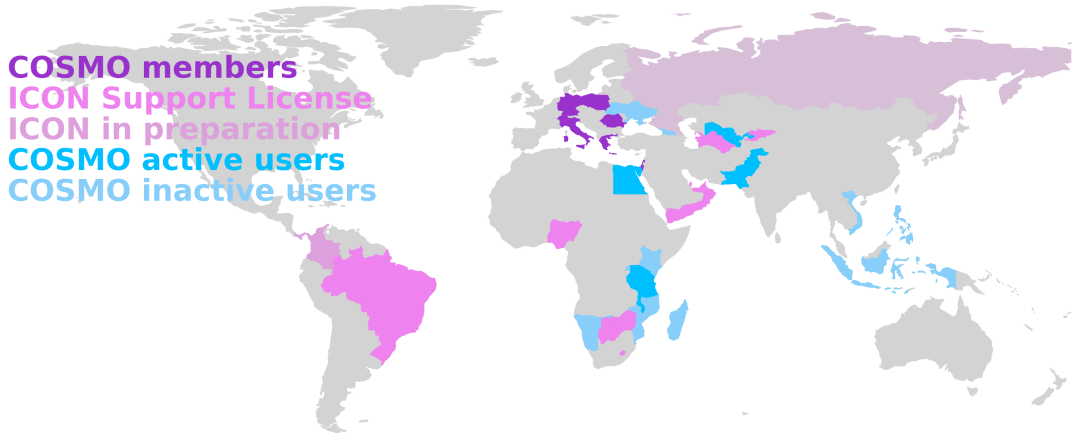
ICON support licence – an overview

Ulrich Schättler, Christoph Gebhardt (DWD)

Along with the transition from the COSMO model to the ICON modelling framework as the consortium's core model for operational forecasting, a new support licence for the ICON model as operational NWP application is issued by the consortium. Holders of the licence for COSMO code and support are encouraged to consider a transition to ICON and the ICON support licence for their operational duties.
The new ICON support licence has a modified scheme for licence fees with a coupling to the gross domestic product per capita resulting in reduced fees for many countries as compared to the former COSMO licence. To ensure an efficient support service for the licensees, the work flow is optimized with a request tracker software and a single point of contact for support inquiries via e-mail at icon-support@cosmo-model.org.

Operational services of eleven countries have signed the ICON support licence by May 2025, i.e. Botswana, Brazil, Kyrgyzstan, Lesotho, Nigeria, Oman, Qatar, Turkmenistan, United Arab Emirates, Yemen, and Zimbabwe. ICON licences are currently prepared for Colombia and Panama.
The map below gives an overview of countries with an ICON support licence and the COSMO members together with further countries which are using the COSMO licence actively or are currently inactive.

As you know, a lot of work in the user support has been carried out by Bogdan Maco of NMA. Since April, he decided to leave NMA to start a new adventure. Therefore we would like to thank him for the huge contribution and the fruitful collaboration in our Consortium during the years.



Map of ICON (active and in preparation) and COSMO (active/inactive) licensees together with the COSMO member countries.

The RDP Paris 2024 Olympics

JAN-PETER SCHULZ (DWD, CMCC)

In preparation for the WMO WWRP Research Demonstration Project (RDP) Paris 2024 Olympics, its 2nd General Assembly was organized by Dr. Valery Masson (MeteoFrance, CNRM) on 12-14 December 2023 at MeteoFrance in Paris. The participants were about 50 internationally leading scientists in the field of urban sciences, specialized in high-resolution hectometric-scale modelling, nowcasting, observation, and social science.

The RDP modelling component includes an intercomparison of the participating urban models. The aim is to understand the model behaviour on the hectometric scale, and if the parameterisations, which were initially developed for the kilometer-scale, are still valid at a hectometric scale. Furthermore, the impact of the city on local meteorology is studied, for both heatwaves and thunderstorms, with a special focus on the organization of thunderstorms. Beside the model itself, also the role of the land cover dataset, or the urban canopy parameters, is evaluated.

I gave a presentation on "The Paris heat wave on 17 Jun. 2022 simulated by ICON-LAM at 500 m". Figure 1 shows the impervious surface area in the common simulation domain, based on the land use dataset GlobCover, the city of Paris is depicted in the center of the domain. I carried out two ICON-LAM simulations for this case study, one with the urban parameterisation switched off (REF), in the other it is switched on (URB). Figure 2 shows the difference of the 2-m temperature on 18 June 2022 at 0 UTC between the two simulations. Switching on the urban parameterisation increases the 2-m temperature in the city at night by about 3 °C on average. This is in agreement with observations.

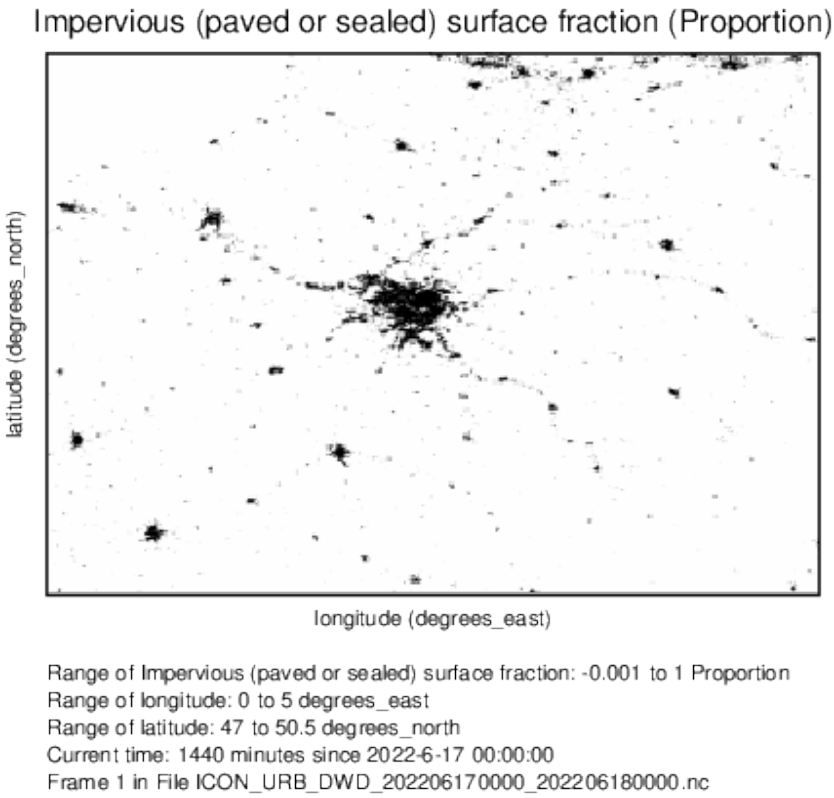


Figure 1. Impervious surface area in ICON-LAM in the common simulation domain around Paris.

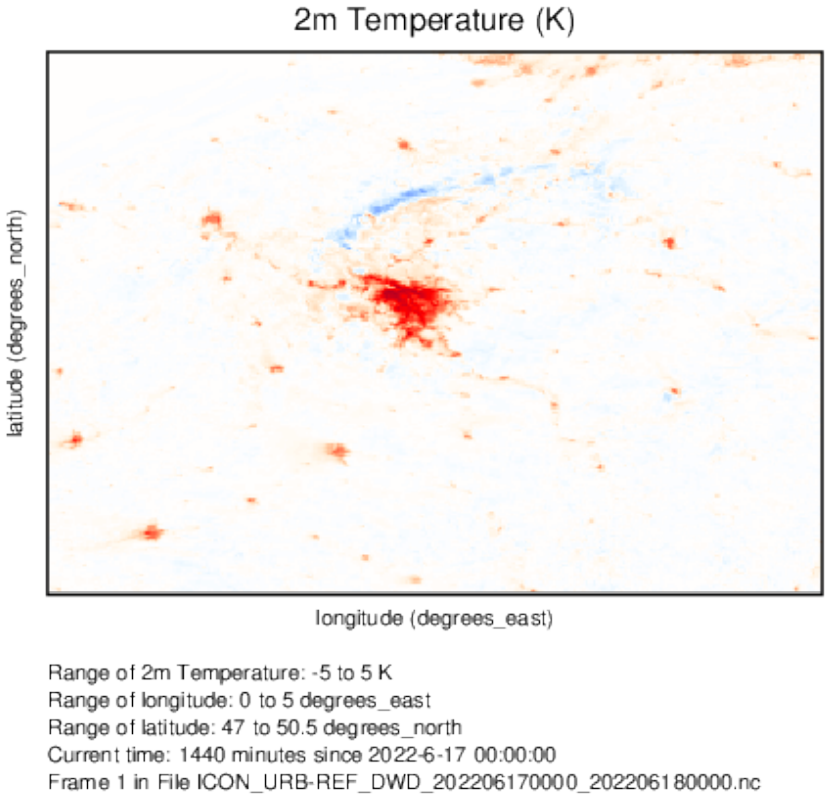


Figure 2. Difference of the 2-m temperature on 18 June 2022 at 0 UTC between the urban parameterisation in ICON-LAM switched on and off, activating the urban parameterisation increases the 2-m temperature in the city at night by about 3 °C on average.

During the year 2024 more detailed model intercomparisons were carried out in order to address the research questions mentioned before. Furthermore, "quasi-operational" forecasts were made with the different models participating in this RDP, in order to provide weather forecasts and warnings for the Olympic and Paralympic Games in 2024. During the Games, every day at 16 CEST the participating scientists met for an online video conference to discuss the synoptic situation over Paris the day before and the corresponding model performances of seven participating weather forecast models run at hectometric scale. For verification, seven dedicated measurement stations in the urban, sub-urban and rural areas were available, together with radar measurements. The observation period included heat waves as well as thunderstorm cases.

The RDP Paris 2024 Olympics provided the outstanding opportunity to compare and evaluate seven internationally leading atmospheric models run at hectometric scale for an observation period of about seven weeks. Generally, heat waves were forecasted well, with a tendency of some overestimation by some of the models. Instead, precipitation particularly during thunderstorms and convective events turned out to be much more challenging for all of the models, including a scale dependence of the models at hectometric scale.

ACLIIM workshop at DWD, January 2025

HAREL MUSKATEL, PAVEL KHAIN (IMS)

In late January 2025, researchers Harel Muskatel and Pavel Khain from the Israel Meteorological Service participated in an ACLIIM (Aerosol-Cloud Interactions in ICON Model) workshop at the German Weather Service (DWD). The workshop, funded through a COSMO activity proposal, enabled collaborative work with DWD scientists to explore various aspects of ICON's microphysical schemes.

Towards Advanced Aerosol-Cloud Interactions in ICON Model

The ICON model's radiation scheme (ecRAD) has been enhanced through its integration with three-dimensional aerosol data from the Copernicus Atmosphere Monitoring Service (CAMS). This advancement, implemented through the COSMO priority project CAIIR (Clouds and Aerosols Improvements in ICON Radiation scheme), enables more precise evaluation of cloud droplet number concentrations (CDNC) - a critical factor in cloud formation, reflectivity, and radiation fluxes. Building on this foundation, the new ACLIIM priority project aims to implement more sophisticated CDNC parameterizations. The project's initial phase couples eleven CAMS aerosol species, both forecasted and climatological, with the Segal & Khain (2006) cloud droplet activation scheme (SK2006). This integration process involves calculating activatable aerosol particle concentrations from CAMS 3D data and combining them with vertical speed and aerosol size distribution parameters—specifically mode radius and geometric standard deviation—as inputs for SK2006. The resulting CDNC calculations are utilized across various ICON schemes, including microphysics, radiation, and convection. Our workshop discussions centred on optimizing the code architecture to ensure both simplicity and unified implementation.

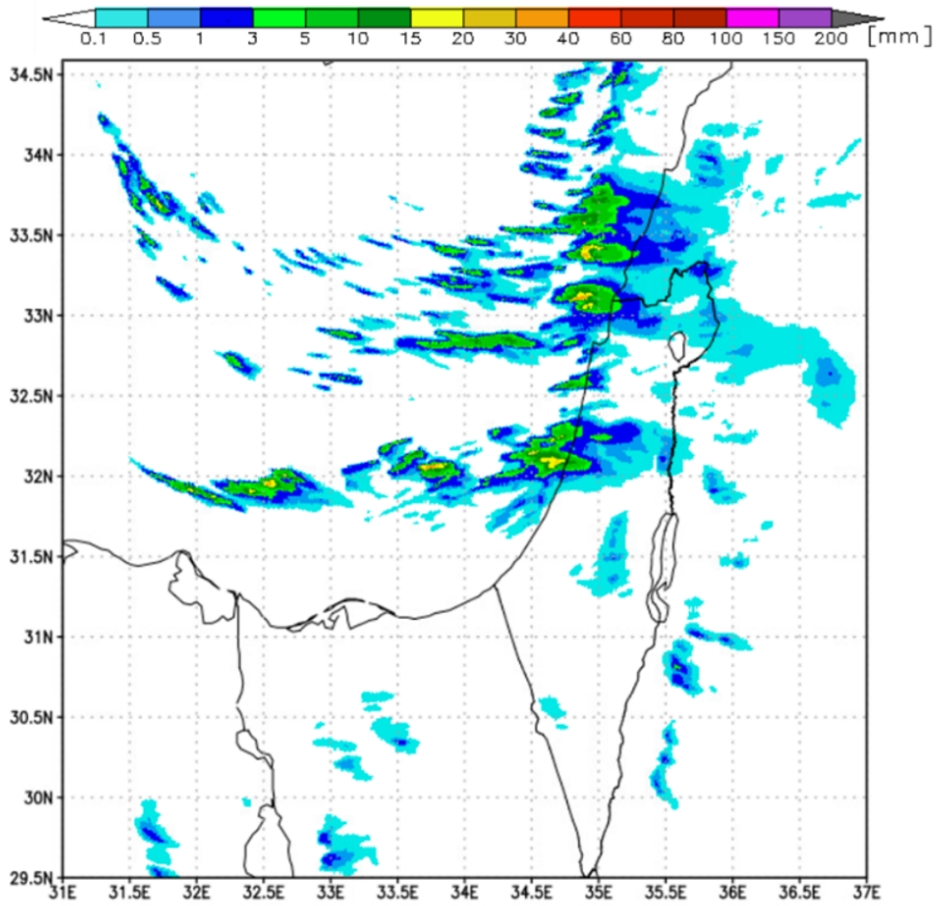
The workshop also explored an alternative droplets activation approach using a sophisticated parcel model developed by Rothenberg and Wang (2016). Their model, pyrcel, enhances the adiabatic cloud parcel framework previously established by Nenes et al. (2001) and Seinfeld and Pandis (2006). At its core, pyrcel numerically solves a system of ordinary differential equations, taking user-specified aerosol compositions as input—in our implementation, we use CAMS aerosol data. The model requires initial parcel conditions including updraft speed, pressure, supersaturation, and temperature. During our discussions, we focused on defining appropriate variable boundaries and efficient methods to systematically sample the model's parameter space, such as Monte Carlo simulations to cover the multidimensional parameter space. These simulation results will form the foundation for developing a machine learning model, which will ultimately be plugged into ICON through the ComIn interface.

Mixed-phase spectral-bin microphysics in ICON

The ICON model employs various microphysical parameterizations. While the 1-moment (1M) scheme serves as the operational standard across COSMO consortium models, the SYNFONY project stands apart in its use of the 2-moment (2M) scheme. In parallel, an advanced microphysical scheme that combines machine learning with Lagrangian super-particle modelling techniques is being developed (Seifert and Siewert, 2024).

The integration of the Spectral-Bin Microphysics (SBM) scheme into ICON has been progressing steadily. A significant milestone was reached in summer 2023 with the official implementation of the "warm-phase" SBM version. Building on this foundation, development has expanded to incorporate mixed-phase processes. The scheme now encompasses 33 tracers for each of the particle species: CCN, liquid droplets, ice/snow and graupel/hail hydrometeors (132 in total). Adapted from WRF's "Fast SBM" version, these mixed-phase processes have been successfully validated through both idealized and real-case simulations.The complete implementation has been recently merged into ICON's NWP master branch.

The computational demands of ICON with Spectral Bin Microphysics (SBM) are substantial, executing 10-20 times slower than ICON with one-moment microphysics. While strategies to optimize simulation speed are under consideration, such as selectively omitting the advection of negligible mass-bins, SBM's high fidelity makes it an invaluable benchmark for evaluating both one-moment and two-moment ICON simulations. A key focus is the comparative analysis of residual super-saturation in updrafts, contrasting the parameterized approaches used in one-moment and two-moment schemes against SBM's detailed calculations. Additionally, through a recent collaboration with IMS colleagues at DWD, work has begun to integrate SBM into the Efficient Modular VOlume RADar forward Operator (EMVORADO).



Example of ICON-SBM (1km-res) precipitation forecast: 7-8 UTC 4/1/2020

[1] Segal, Y. and A. Khain, 2006: Dependence of droplet concentration on aerosol conditions in different cloud types: Application to droplet concentration parameterization of aerosol conditions. *J. Geophys. Res.*, 11, D15204. doi: 10.1029/2005JD006561

[2] Rothenberg, D. and C. Wang, 2016: Metamodeling of Droplet Activation for Global Climate Models. *J. Atmos. Sci.*, 73, **1255–1272**. doi: 10.1175/JAS-D-15-0223.1

[3] Nenes, A., Ghan, S., Abdul-Razzak, H., Chuang, P. Y., and J. H. Seinfeld, 2001: Kinetic limitations on cloud droplet formation and impact on cloud albedo. *Tellus B*, 53, **133–149**. doi: 10.3402/tellusb.v53i2.16569

[4] Seinfeld, J. H. and S. N. Pandis, 2006: Atmospheric Chemistry and Physics: From Air Pollution to Climate Change. *Wiley, 3rd Edition, 1152 pages ISBN 978-1-118-94740-1*

[5] Seifert, A. and C. Siewert, 2024: An ML-Based P3-Like Multimodal Two-Moment Ice Microphysics in the ICON Model. *J. Adv. Model. Earth Syst.*, 16. doi: 10.1029/2023MS004206

COSMO activity proposals

COSMO grants funding for activities related to the scope of COSMO following an approval process. The funds for approved **COSMO activity proposals** are provided by the licence fees for the ICON and COSMO support licences.

In recent months, the following activities have been supported:

- Visits by Harel Muskatel and Pavel Khain at DWD (8 - 11 April 2024 and 27 - 30 January 2025; see short report in this COSMO NL)
- Seed funding of **TEAMx** ('Multi-scale transport and exchange processes in the atmosphere over mountains – programme and experiment')
- Evaluation of ICON forecast products during the 2024 Testbed of the European Severe Storms Laboratory (**ESSL**)
- Financial support of **ICCARUS 2024** in Offenbach, Germany, 4-8 March 2024
- Financial support of the **Numerical Model Training courses 2024** and **2025** for ICON in Offenbach, Germany, 10-14 June 2024 and 12-16 May 2025
- Travel support for participation in the **EWGLAM 2024** in Prague, Czech Republic, 30 September - 3 October 2024
- Travel support for participation in the **European Nowcasting and Weather Forecasting Conference** in Oslo, Norway, 4-8 November 2043
- Travel support for participation in **ICCARUS 2024** and **ICCARUS 2025** in Offenbach, Germany, 4-8 March 2024 and 10-14 March 2025

COSMO General Meeting 2024

CHRISTOPH GEBHARDT (DWD)

The 26th COSMO General Meeting, which is held annually to present results, deliverables, and progress reports from the Priority Projects and Working Groups, took place from 2nd to 6th September 2024 in Offenbach am Main, Germany. The event was organized by the German Meteorological Service (DWD).

The 2024 COSMO General Meeting combined familiar components with innovations aimed at strengthening the cooperation within the ICON community. COSMO not only benefits from this cooperation, but contributes to the ICON community with its focus on operational numerical weather prediction.

As in previous years, the programme was composed of parallel meetings of the COSMO working groups (WGs) on the first two days, followed by plenary sessions from Tuesday to Thursday. The WG meetings focused on in-depth scientific discussions of WG tasks and COSMO Priority Projects & Priority Tasks. However, beyond the internal COSMO tasks, further innovative activities were incorporated into the presentations and discussions of the Working Groups, such as the digital twin **Global-to-Regional ICON – GLORI**, or Earth System Modelling at the Weather scale – ESM-W, a collaboration between the DWD and the Geoinformation Service of the Bundeswehr (German Armed Forces) to develop forecasts for the coupled ocean-atmosphere system. A successful new approach was the joint organization of the "Radiation, Clouds, Aerosols and Chemistry" WG meeting by the ICON partner **KIT** and COSMO. The broader composition of the WG meetings, with the active inclusion of projects outside of the specific COSMO PPs and PTs, is a key success of the COSMO GM 2024.

After the official opening of the meeting by the Chairman of the COSMO Steering Committee, Panagiotis Skrimizeas, and welcoming addresses from Prof. Dr. Sarah Jones (President of DWD) and Prof. Dr. Peter Braesicke (Head of the DWD's Earth System Division), the plenary sessions provided an overview of developments in the COSMO WGs. Further contributions were presented by the cooperating partners of COSMO: **KIT**, the **Climate Limited-area Modelling Community – CLM**, the **EUMETNET module Coordination on short-range numerical weather prediction – C-SRNWP**. Most contributions can be found on the meeting webpage.

A special feature of this year's General Meeting was the addition of short overview presentations by each COSMO country, which provided an update on their current status in operational numerical weather prediction. This format was well received and will be a regular part of future General Meetings. Furthermore, the Italian **Center of Excellence "Telesensing of Environment and Model Prediction of Severe events" – CETEMPS** introduced itself as new official partner to the COSMO community in the plenary session.

After the conclusion of the plenary sessions with the report from the Steering Committee, the meeting of the Scientific Coordination Committee (SMC) took place on Thursday afternoon and Friday morning, where the key aspects of the working groups and general technical issues related to COSMO were discussed. Additionally, organizational aspects and new ways of cooperation between COSMO and the ICON community were also important topics of discussion in the SMC.

The meeting's excursion was an informative and enjoyable event, which included a city tour of Frankfurt, a visit to one of the city's museums (Senckenberg Natural History Museum, Historical Museum Frankfurt, or Museum of Communication), and a concluding dinner at a traditional apple wine tavern in the Sachsenhausen district.

In hindsight, the COSMO General Meeting 2024, with approximately 70 participants, was a very interesting and successful event with proven as well as new concepts and approaches, which were motivating for future cooperation within the COSMO consortium itself and within the broader ICON community.

COSMO sincerely thanks the organizing team for making the execution of this successful General Meeting possible.

We look forward to the next COSMO GM, which will be held from 1th to 5th September 2025 at the University of Basel, Switzerland, organized by MeteoSwiss.

Participants of the 25th COSMO General Meeting in Offenbach, Germany

EWGLAM Meeting 2024

CHIARA MARSIGLI (ARPAE)

Every year, at the beginning of the Autumn, the Meteorological Services in Europe meet in an event dedicated to Numerical Weather Prediction (NWP), with a particular focus on limited-area modeling. The European Working Group on Limited-Area Modeling initiated this activity in 1979, giving birth to the EWGLAM Meeting, which, since 1994, has also become the Meeting of the **SRNWP**, the Programme of EUMETNET dedicated to Short-Range NWP.

In 2024 the 46th EWGLAM and 31st SRNWP meeting took place in Prague, hosted by the Czech Hydrometeorological Institute (**CHMI**) and organised by the C-SRNWP Module of the EUMETNET Programme E-WFC (EUMETNET Weather Forecasting Cooperation). The C-SRNWP Module, which is coordinated in the present phase by the Deutscher Wetterdienst, provides the resources for the scientific organisation of the meeting and for supporting the local organisers.

From the 30th of September to the 3rd of October 2024 about 90 scientists from 29 different countries met in Prague to present and discuss their recent results about all aspects of the NWP. The programme was organised in sessions: data assimilation, model dynamics, predictability and ensemble, verification, physics parametrisation for both atmosphere and land surface, applications.

The presentation focussed on new challenges like the development of the models for the hectometric scale, verification for high-resolution NWP and for high-impact weather, usage of non-conventional observations for data assimilation and verification, the growing usage of AI-based methods in many different aspects of the forecasting, the ongoing process towards integrated Earth Systems Modeling forecasting systems. Lively discussion took place during the sessions as well as at the end of the meeting, to identify the main issues, the most promising lines of developments and to initiate collaborations. The meeting is a unique opportunity for maintaining and reinforcing the cooperation between the European modeling Consortia, and the benefits for COSMO are appreciable throughout the years.

The participants came mainly from Meteorological Services in Europe, but also from universities and research centres, and, as it is meanwhile a tradition, a guest from the Japanese Meteorological Agency (JMA) also participated in the meeting. Harold Brooks from the National Severe Storms Laboratory of NOAA (US) was invited to share his experience on severe convective storms and their evaluation and verification, and gave the talk: “If a Picture’s Worth a Thousand Words, Visualizing Aspects of Performance Might Be Worth a Chapter”.

The hospitality of the Czech colleagues has contributed to the success of the meeting and to maintain the collaborative and enjoyable atmosphere which characterizes the EWGLAM meeting. A mention needs to be made to the social dinner on Wednesday evening, which, as is tradition, hosted a very special singing event. The participants courageously presented traditional songs from the different countries to the colleagues, alternated with pop songs, producing a truly international music festival sung in almost all the languages represented in the meeting.

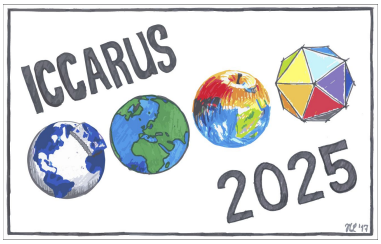
The next EWGLAM meeting will take place in Norrköping from the 22nd to the 25th of September 2025, hosted by the Swedish Meteorological and Hydrological Institute (SHMI).

All the interested COSMO scientists are invited to participate with their latest scientific results and their best song!

ICCARUS 2025

DANIEL RIEGER, CHRISTIAN STEGER, CHRISTOPH GEBHARDT (DWD)

ICCARUS (ICON/COSMO/CLM/ART User Seminar) 2025 took place at the DWD headquarters in Offenbach from March 10 to 13. Over the past two and a half decades, the annual meeting has established itself as a hub for the exchange of information on model development, physical parameterization, data assimilation, ensemble generation, verification and applications around the COSMO and ICON models. The event connects the COSMO and CLM community as well as ICON and ART developers.



The event was opened by DWD's new Head of Research and Development, Peter Braesicke. Roland Potthast then gave an overview of how numerical weather prediction and AI forecast models complement each other. This was followed by the start of the scientific lecture program. This year, it comprised a total of 44 lectures on Monday, Tuesday, and Wednesday, which were divided into the thematic units "Atmospheric Aerosol", "Climate Applications", "Infrastructure", "Clouds", "SINFONY (Project)", "NWP Case Studies", "Dynamics / Gravity Waves", "Data Assimilation", "CONTRAILS (Project)", "Dynamics", 'Chemistry' and "Earth System Modeling".

The program was enriched by four keynote speeches by Ali Hoshyaripour (KIT) on "ICON-ART: Updates, Enhancements, and What Lies Ahead" and "Evolving Excellence: Updates and Vision for ICON", Claudia Frauen (DKRZ) on "WarmWorld - Exascale Earth System Models to Anticipate Changes in a Warmer World", Christoph Müller (MeteoSwiss) on "Towards a performance portable python implementation of the ICON model" and Günther Zängl (DWD) on "ICON-NWP: Recent development steps and operational upgrades, and plans for 2025".

The poster session took place on site for the first time since 2019. A total of 68 posters were presented in three poster sessions. The exchange at the posters brought some variety to the tight lecture program in the afternoon. On Monday evening, after the scientific program, there was a reception for the participants in Offenbach.

The working group meetings, which took place on Thursdays or online the following week, were based on the well-proven concept from the previous year. The main aim is to bring the developers and users of the ICON model from the various communities (COSMO, CLM and ICON) closer together in order to facilitate a better exchange and intensify collaboration. The working groups covered the topics "Soil, Vegetation & Land Surface", "ICON AI", "Earth System Model", "Data Assimilation", "Ensemble", "Model Dynamics", "Atmospheric Boundary Layer", 'Evaluation', "Radiation, Cloud, Aerosol, Chemistry" and "ICON Consolidated (ICON-C)".

The total number of registered participants for ICCARUS 2025 was 347. Of these, 155 people were on site in Offenbach. There was a total of 112 scientific contributions (44 presentations, 68 posters). These numbers impressively demonstrate the great interest in ICCARUS and its importance for the exchange between developers and users of ICON at universities, research institutions and national meteorological services. The date for ICCARUS 2026 will be announced later this year. It will depend on the availability of rooms in Offenbach and the avoidance of weeks with major trade fairs in Frankfurt. However, it will most likely be in March 2026.

Participants of the 25th COSMO General Meeting in Offenbach, Germany

European Nowcasting and Weather Forecasting Conference 2024

MASSIMO MILELLI (CIMA), CHIARA MARSIGLI (ARPAE)

The European Nowcasting and Weather Forecasting Conference 2024 (ENWFC-2024) was organised under the framework of EUMETNET (the European Meteorological Network), specifically within the EUMETNET Weather Forecasting Cooperation (E-WFC) Programme and the majority of its modules: E-NWC (EUMETNET Nowcasting), PP (Post-Processing), and SRNWP-EPS (Short-Range Numerical Weather Prediction – Ensemble Prediction System). DWD coordinates the SRNWP-EPS Module and some COSMO members are also members of the E-WFC Programme.

This event continued the legacy of the European Nowcasting Conference series and, for the first time, was jointly hosted within the scope of the three aforementioned modules. The conference was dedicated to topics including Nowcasting, Very Short-Range Forecasting (VSRF), Seamless Forecasting, Ensemble Prediction, and Post-Processing.

The primary aim of ENWFC-2024 was to foster and showcase recent advances in both the theoretical and practical aspects of these areas, not only within Europe but also internationally.

The conference welcomed participants from operational services, the research community, and end-users of forecasts. The keynote talks addressed topics which are currently debated also in the Consortium, e.g. the contribution by Zied Ben Bouallegue (ECMWF) on "Evaluation of ML models: from forecast verification to model falsification".

Importantly, ENWFC-2024 provided a valuable platform for collaboration and knowledge exchange within the COSMO consortium (represented by many colleagues, including Chiara Marsigli as chair of a session) and the other European Consortia. As a key community in the development and application of high-resolution numerical weather prediction, COSMO greatly benefits from the discussions, shared experiences, and scientific progress presented at such events. The conference strengthened ties between COSMO members and the wider European nowcasting community, supporting innovation and coordination in weather forecasting across the continent.
The Book of Abstracts is available here:
https://drive.google.com/file/d/1qGuuZfXc_yviePTTppUZJfVGcDZkhD-A/view and the full Programme with Presentations can be accessed here:
https://enwfc-2024.met.no/programme.

Numerical Model Training Course 2025

Daniel Rieger (DWD), Stefan Gabrian (NMA), Stefan Dinicila (NMA), Witold Interewicz (IMGW-PIB), Uli Schättler (DWD)

From May 12 to 16, the Numerical Model Training Course 2025 for the ICON model took place at the DWD headquarters in Offenbach, Germany. The local organizing team from DWD received further support from the COSMO partners and members of the CLM community.

The areas of application of the ICON model range from numerical weather prediction (NWP) and regional climate simulations (CLM - Climate Limited Area Model) to the prediction of trace substance dispersion with ICON-ART. Therefore, national weather services, universities and research institutions are among the target group of the training course. Last but not least, the training course also serves to establish contacts between the ICON users and the ICON developers at DWD.

The morning program consisted of lectures on the physical principles and technical details of the ICON model. In the afternoon, the participants were able to learn how to carry out ICON simulations in the exercise blocks. For the exercises, we were able to rely on the proven concept from previous years of offering exercises with different thematic focuses for different areas of application, namely regional climate simulations ("CLM") and NWP for national weather services ("MetServices"). In contrast to previous years, there were no exercises focusing on NWP for the academic sector. These will take place in July as part of natESM at the DKRZ in Hamburg (https://www.nat-esm.de/services/workshops-and-trainings/events/dwd-academic-icon-course-dkrz).

Of the 67 participants who were accepted for the course, only 28 were ultimately present. Although not everyone showed up in previous years also, this high proportion came as a surprise to the organizing team. As usual, the course was very international, this year with participants from Botswana, Germany, Italy, Cameroon, Nigeria, Oman, Romania, Switzerland, Senegal, Zimbabwe and Türkiye. The course took place at the DWD headquarters in Offenbach. The participants brought their own notebooks for the exercises. Calculations were carried out on Levante at the German Climate Computing Center DKRZ (CLM) and on the ATOS system of the ECMWF (MetServices).

After an introductory lecture that presented many technical details about ICON, there were lectures on initial and boundary data, dynamics, physics overview, advection, nesting and ICON limited-area mode, microphysics, clouds and convection, radiation, gravity wave drag, turbulence, soil and external parameters, lakes and sea ice and ICON-ART.

The CLM exercises were designed and conducted by the CLM community. The course introduced the Starter Package for ICON-CLM Experiments (SPICE). SPICE is a runtime environment for performing regional climate simulations with ICON-CLM. SPICE was developed within the CLM community. The CLM course was rounded off with a ComIn exercise (ICON Community Interface). The exercises for the national weather services were created by the COSMO Consortium. The focus was on high-resolution ICON-LAM simulations and the tools required for operational use (ecflow scheduler, verification).

Guided tours through areas of the DWD provided a change from the intensive course program. The participants were able to visit the HPC, the library archive, radioactivity monitoring, the forecasting and advice center and the Global Precipitation Climatology Centre (GPCC) at DWD. Despite the low number of participants overall, the tours were very well attended.

Group picture, source: M. Kügler (DWD)

Events 2025

We would like to draw your attention to the following events:

- **12th International Conference on Urban Climate**
  7th – 11th July 2025 in Rotterdam, The Netherlands.
  Please visit the **event page** for registration and more information.

- **DWD Academic ICON Course** for participants from academia organized by DWD with the natESM project@DKRZ and KIT
  21st – 25th July 2025 in Hamburg, Germany.
  Please visit the **seminar page** for information.

- **27th COSMO General Meeting**
  1st – 5th September 2025 in Basel, Switzerland.
  Please visit the **event page** for registration and more information.

- The **2025 Annual Meeting of the European Meteorological Society** (EMS)
  7th – 12th September 2025, in Ljubljana, Slovenia.
  Please check the **meeting page** for all details.

- **47th EWGLAM** & **32nd SRNWP meetings**
  22nd – 25th September 2025 in Norrköping, Sweden, hosted by the Swedish Meteorological and Hydrological Institute (SMHI).
  Comprehensive information including the registration form is available on the **meeting page**.

- The **15th EUMETNET Data management workshop**
  4th – 6th November 2025 in Oslo, Norway.
  Please visit the **event page** for registration and more information.

- The **12th European Conference on Severe Storms**
  Utrecht, Netherlands - 17 to 21 November 2025.
  Please visit the **event page** for registration and more information.

- The **ICCARUS 2026** (ICON/COSMO/CLM/ART USER Seminar) will take place in spring 2026 in Offenbach am Main, Germany.
  To avoid high costs for accommodation, the exact dates are to be specified in the coming weeks depending on the schedule of fairs in Frankfurt. Announcement will be done via the usual channels.
  Please check on the **DWD homepage** regularly as well.

Verification in COSMO consortium

FLORA GOFA (HNMS)

Statistical performance evaluation for main weather parameters is derived using the operational ICON-LAM model implementations in each service. The domains (common), the resolution, the statistical scores/methods and the graphical representation approaches, are described in the **annual guidelines**. Common verification software is used for both point wise and neighborhood approach verification which allows for a homogeneous, standardized and objective way to apply, calculate and present statistical scores. The complete seasonal statistical plots can be viewed interactively at the **COSMO shiny server**. Time series (TS) plots of ME for the last four years are given below for 10m wind speed (WindSp) and 2m temperature (2mT), summarising the performance of all available ICON-LAM and COSMO implementations over Common Area 2.
The 2mT ME (for 12UTC) is reduced with ICON-LAMs with a tendency to overestimation during the warmer months while the daily cycle in error is drastically reduced too. WindSp ME range exhibits less significant change with the introduction of ICON-LAMS but with a change in the phase of error (overall slight underestimation).

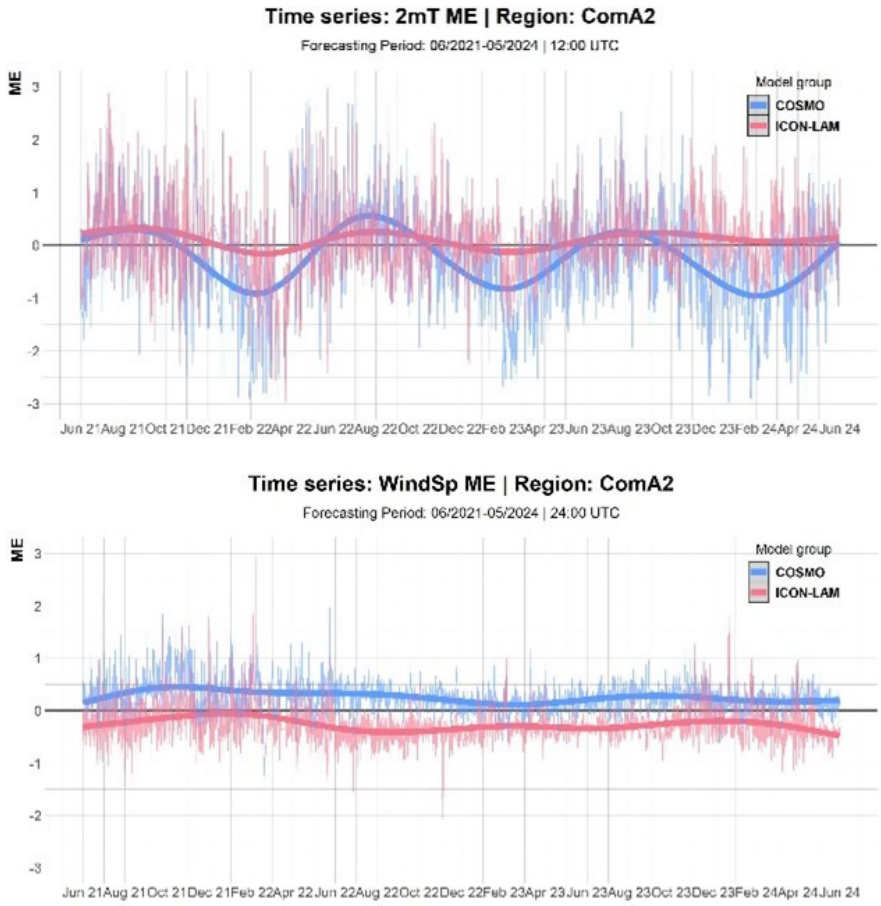


Figure 1. TS based on all COSMO/ICON models, top:2mT ME at 12:00 UTC, bottom: WindSp ME at 12UTC.

In the Heat Map in Figure 2, the performance of all ICON-LAMs over Common Area 2 is presented for a period of four years with respect to ME with the forecast horizon. For WindSp, the slight underestimation is confirmed in all forecast times for the last two years. An overestimation for 2mT is evident during warm months, while an underestimation in winter months warm hours. For total cloud cover (N), the overestimation at night and in warm months is the most striking outcome, while for 2mTd, there is a clear underestimation mainly in winter and specifically during night time.

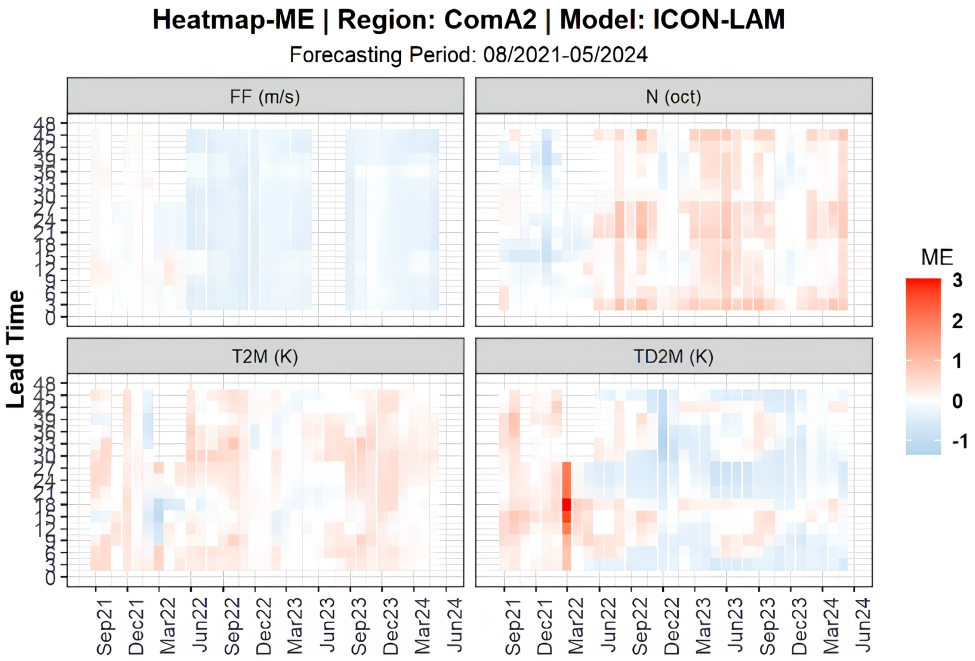


Figure 2. HeatMaps for ICON-LAMs performance calculated over 2021-2024.

News/Meetings: An online meeting on Model Errors based on Common Verification results took place on 21.01.2025. The focus was given to the performance of ICON implementations, reporting on systematic errors and tuning performed based on them. The presentations are available on the COSMO web page.

Below two examples of the impact of model tuning are shown:

a. Reduction of temperature biases in urban areas with the implementation in ICON-D2 of Terra-URB (parameterization designed to better simulate surface-atmosphere interactions in urban environments).

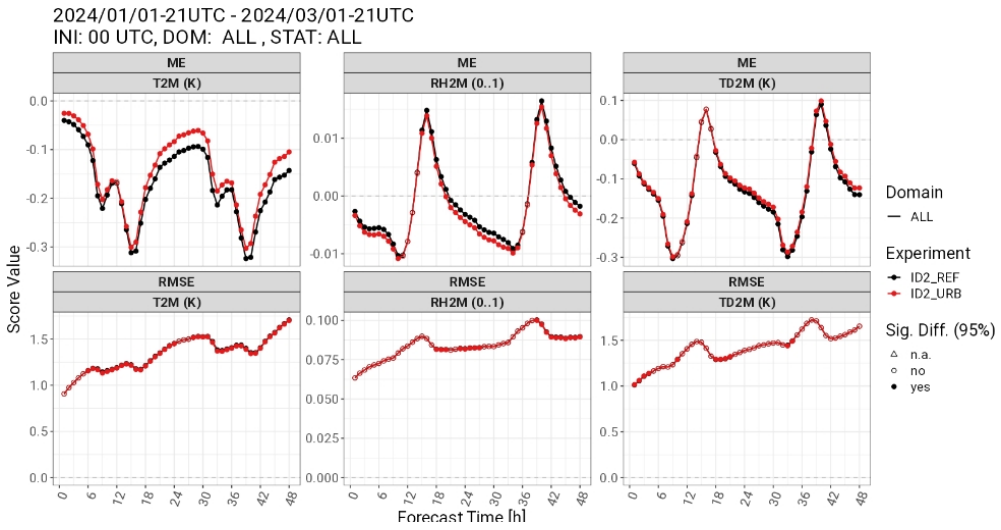


Figure 3. Impact of Terra Urb scheme (red line) on the performance (ME, RMSE) of 2mT, RH and 2mTd.

b. Modifications in 1-moment graupel scheme and saturation adjustment to deal with overestimation of high precipitation intensity. Various adjustments (tune_supsat_limfac, lvariable_rain_n0, tune_zcsg, ithermo_water, tune_sgsclifac) and reduced grayzone deep convection are indicating a reduction of precipitation maxima overestimation.

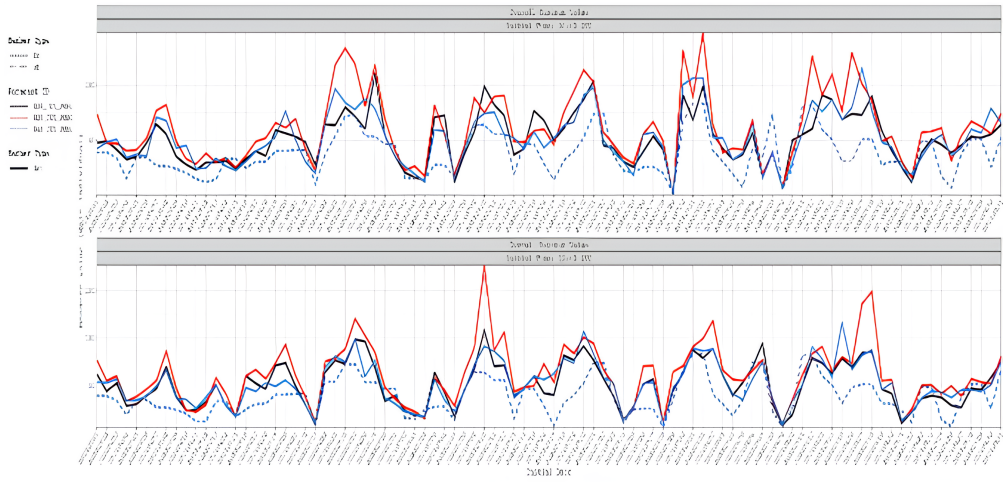


Figure 4. Impact of various modifications (solid lines) on ICON-D2 maximum precipitation forecasts for summer 2024 against observations (dotted line).

Direct Numerical Simulations of Strongly Stable Boundary-Layer Flows over Thermally Heterogeneous Surfaces

DMITRII MIRONOV (DWD), PETER SULLIVAN (NCAR)

A paper "Turbulence structure and mixing in strongly stable Couette flows over thermally heterogeneous surfaces: effect of heterogeneity orientation." by D. Mironov and P. Sullivan was published in *Flow Turbul. Combust.* (2025, vol. 114, p. 967–994). The study of Mironov and Sullivan (2025) extends previous studies by the authors (Mironov and Sullivan, 2016, 2023). The aim of these studies is to improve our understanding of the structure and transport properties of stably stratified boundary layers (SBLs), particularly those over heterogeneous surfaces, and to develop advanced parameterizations of SBLs in numerical models of environmental flows. A brief summary of results reported by Mironov and Sullivan (2024) is given below.

Direct numerical simulations (DNS) of stably stratified plane Couette flows over thermally heterogeneous surfaces are performed. A plane Couette flow configuration with bulk Reynolds number of $Re = 10^4$ is used as a proxy for real-world SBLs. The major focus of the study is the effect of the surface heterogeneity orientation on the boundary-layer structure and transport properties. In the Couette flow configuration used, the temperature of the upper and lower walls is either homogeneous or varies sinusoidally, where the temperature-wave crests are either normal or parallel to the mean flow (HETx and HETy cases, respectively). The horizontal-mean surface temperature is the same in both homogeneous and heterogeneous simulations.

The stratification at bulk Richardson number of $Ri = 0.25$ is strong enough to extinguish turbulence over a homogeneous surface. However, turbulence survives over heterogeneous surfaces. In all heterogeneous cases, both molecular diffusion and turbulence transfer momentum down the gradient of mean velocity. The total, i.e., turbulent plus diffusive, heat flux is down-gradient. However, quasi-organized boundary-layer scale eddy motions generated by the surface thermal heterogeneity induce heat transfer that is up the gradient of the mean temperature. The situation is similar to that in convective boundary layers driven by the surface buoyancy flux, where counter-gradient heat transport is often encountered. It is attributed to quasi-organized eddy structures (convective plumes and rolls), whose spatial scale is large as compared to the scale of chaotic, nearly isotropic turbulence. Comparative analysis of HETx and HETy cases shows that the configuration with the spanwise heterogeneity is more efficient in transporting momentum and heat vertically than the configuration with the streamwise heterogeneity. Vertical profiles of mean fields and turbulence moments differ considerably between the HETx and HETy cases, e.g., the streamwise heat flux differs not only in magnitude but also in sign. Analysis of the second-order turbulence moments, vertical-velocity and temperature skewness, and the flow eddy structure suggests a physically plausible explanation of the observed differences between the HETx and HETy cases.

The implications of the DNS findings for modelling turbulence within the Reynolds-Averaged Navier-Stokes framework are discussed. A physically sound turbulence closure model (parameterization scheme) that accounts for the effect of the surface thermal heterogeneity, including the orientation of the heterogeneity patterns, is still to be developed. The findings from the present study highlight several important aspects that should be considered when pursuing this goal.

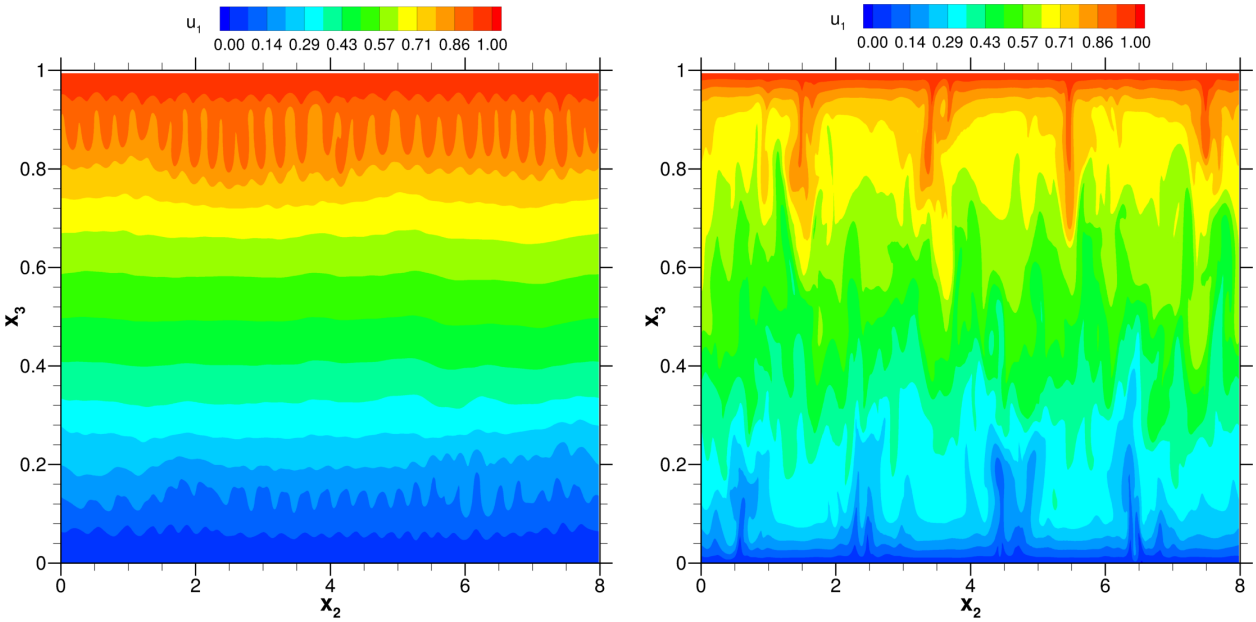


Figure 1. Vertical cross section (normal to the mean flow; x_2 and x_3 are spanwise and vertical directions, respectively) of the streamwise velocity from simulations HET050x (left) and HET050y (right). The cross section is taken in the middle of the flow domain. See Mironov and Sullivan (2025) for details.

[1] Mironov, D. V., and P. P. Sullivan, 2016: Second-moment budgets and mixing intensity in the stably stratified atmospheric boundary layer over thermally heterogeneous surfaces. *J. Atmos. Sci.*, 73, **449–464**. doi: 10.1175/JAS-D-15-0075.1

[2] Mironov, D. V., and P. P. Sullivan, 2023: Turbulence structure and mixing in strongly stable boundary-layer flows over thermally heterogeneous surfaces. *Boundary-Layer Meteorol.*, 187, **371–393**. doi: 10.1007/s10546-022-00766-x

[3] Mironov, D. V., and P. P. Sullivan, 2025: Turbulence structure and mixing in strongly stable Couette flows over thermally heterogeneous surfaces: effect of heterogeneity orientation. *Flow Turbul. Combust.*, 114, **967–994**. doi: 10.1007/s10494-024-00593-9

Further publications

Cavalleri, F., Lussana, C., Viterbo, F., Brunetti, M., Bonanno, R., Manara, V., Lacavalla, M., Sperati, S., Raffa, M., Capecchi, V., Cesari, D., Giordani, A., Cerenzia, I. M. L., and M. Maugeri, 2024: Multi-scale assessment of high-resolution reanalysis precipitation fields over Italy. *Atmos. Res.*, 312. doi: 10.1016/j.atmosres.2024.107734

Newsletter | No.24| 2025
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