**COSMO Priority Project PREVUE (Perturbation, Representation, Evaluation, Verification, and Utilization of EPS): Project Plan**

Version 3, 31.08.2025

**Project leader:**

**xxx**

**Project duration:**

3 years (December 2025 – November 2028)

**Summary**

The COSMO Working Group on Predictability and Ensemble Methods is proposing a new Priority Project. The aim of the project is to coordinate the development of the ensembles run by the COSMO partners and to carry out together some activities identified as higher priority. The activities which have been identified as most needed and gaining the most from the collaboration are: development and test of model perturbations, in particular based on the SPP method; development of more sophisticated and homogeneous methods for the verification and diagnostics of the ensembles; use of ensembles for the nowcasting; evaluating ICON-LEPS and merging it with national EPSs two to create one product. The PP spans a period of 3 years, involving 6 COSMO members and requiring in total 8 FTEs.

**Motivation**

**Status**

…

**Needs**

The ENS Working Group has identified the followings as the main needs for the improvement of the ensemble forecasting:

* Improve the ability of the ensembles to forecast severe weather with good consistency and reliability. This is manifested through a reduction of the outliers, the forecasted probabilities matching the observed frequencies, the ability of the forecast to discriminate between severe and non-severe events.
* Improve the ability of the ensembles to forecast convection and in particular provide probabilistic support for the convection initiation.
* Improve the usage of ensembles for nowcasting purposes, exploiting the probabilistic approach for the nowcasting and very short-range predictions.
* Dispose of robust and common methods and tools for the verification and the diagnostics of the ensemble. This is needed on the one hand to evaluate the ensemble forecasts in a more meaningful and reliable way, on the other hand to support the ensemble development, in particular when performed in a collaboration between different Services.
* Migrate COSMO-LEPS to ICON-LEPS. COSMO-LEPS is a COSMO initiative that needs substantial rethinking. The migration from COSMO-LEPS to ICON LEPS at 7 km resolution was performed, and the techincal migration to the 2.5 km ICON-LEPS is now also computed. However, the convection-permitting LEPS must be verified, and the added value must be demonstrated to justify the computer resources, before it can replace the still currently operational COSMO-LEPS.
* explore the possibility to improve the national EPSs by adding members from the ICON-LEPS.

**Actions proposed**

Keeping in mind the identified needs and considering the available resources, we decided to focus in the Project on few selected activities, combining their higher priority and their matching with the needs of the COSMO meteorological services. Therefore we propose the following actions:

* **Action 1** Improve the representation of the model errors in the ensembles, with a focus on severe weather and convection.
	+ **1.1** On the basis of the most recent scientific results, we propose to tackle this by implementing, developing and testing the SPP method as model perturbation in ICON, benefiting from the ongoing work carried out at DWD in the framework of the GLORI project. A first implementation of the SPP scheme is available in ICON. The action proposed consists of:
		- work on the implementation of the SPP method in ICON for a selected set of physics parameters in different schemes, and bring it to the master code
		- test the perturbation of the single parameters by varying the setup of the SPP scheme, in order to identify the optimal values of the parameters of the scheme for each model parameter
		- perform the tests on different domains and geographical areas, and with different ensembles
		- test the possibility of giving different values of tuning parameters at different parts of the domain
		- test the perturbation of a set of parameters in a complete ensemble set-up, similar to the operational ones
	+ **1.2** Test other model perturbation methods:
		- work on SPPT at MCH?
		- Ongoing perturbation at IMGW? The work of Tatiana?
* **Action 2** Ensembles for nowcasting – very short-range forecasting.

IMS has implemeted a novel methodology to nowcast the precipitation based on a member selection of their ensemble. In this project it is proposed to further develop and test this method.

* + **2.1** Improve the best member selection for precipitation nowcasting. For that purpose, besides surface precipitation, several ICON fields will be verified, such as lightning potential index (versus ground lightning measurements and MTG lightning Imager), cloud cover (versus cloud mask from CM SAF), 3D wind vector verification versus EUMETSAT MTG FCI L2 AMV product, and reflectivity (dbz) verification versus radar reflectivity data.
	+ **2.2** Introduce the best-member approach for surface fields nowcasting. Every hour, ICON ensemble members will be automatically verified versus the synoptic observations during the last hour, and the “best” member will be identified and used for nowcasting of surface fields, such as temperature, relative humidity, wind and gust speed, etc.
* **Action 3** Development of verification and diagnostics and means to compare ensembles (coordinated with WG V/A). This action consists of:
	+ collaborate with WG V/A to the verification of the different ensembles, including ICON-LEPS, with the COSMO software (as achieved by the CARMENs project), in order to have more comparable verification results.

demonstrate relative strength and weakness of different ensembles compared to ICON-LEPS

* + develop and/or test, in collaboration with WG V/A, methods to perform the spatial verification of the ensemble output for precipitation, clouds, objects (thunderstorms)
	+ develop and test diagnostics to assess the ensemble behaviour, in particular the spread/skill relation (include observational error, consider model biases)
		- study the spread of the ensembles in term of precipitation; develop and share suitable methods for this purpose

**Deliverables**

The deliverables of the Project are presented for each subtask. Summarising, the deliverables are:

1. contribute to the implementation of SPP in the ICON code, test and eventually use operationally SPP in the COSMO ensembles
2. coordination on ensemble nowcasting
3. homogeneous verification of the different ensembles
4. comparison ICON-LEPS skill with different ensembles
5. usage of better diagnostics for the spread/skill relation.

**Description of individual tasks**

**Task 0 Project Coordination**

This PP coordinates activities aimed at the development of the ensemble systems of the COSMO Members and at an improved way to assess the ensemble skill and properties. Four COSMO Members are involved, with four different ensembles. The coordination Task deals with the organisation of virtual and physical meetings, writing of minutes and reports, and guaranteeing e-mail exchange. The final report will also provide a review of the status of the COSMO ensembles.

The activities also require coordination with the other Working Group and in particular: **WG V/A** for the verification and diagnostics (score selection and development, metrics for best member selection), **WG PHY** for the model perturbation (selection of suitable parameters for perturbation and analysis of the behaviour of the perturbation), **WG DA** for the nowcasting (best member selection and initalisation of nowcasting). In order to ensure this coordination, members of the other WGs will be invited to the Project meetings where appropriate and dedicated meetings will be organised.

*Deliverable: Meetings, reports, Final Report.*

Participants: xxx (PL): 0.1 FTE/year; all: 0.1 FTE/year; duration: 3 years.

FTEs for Task 0: 0.2/year (0.6)

**Task 1 Model configuration and perturbation**

This Task realises the activities described in the Action 1.

**Subtask 1.1 – SPP in ICON**

At present there is an implementation of the SPP method in the master version of ICON, consisting of a Stochastic Pattern Generator (SPG) and a perturbation method based on the SPG for few parameters of ICON physics (2-mom microphysics scheme, convection scheme, land-surface scheme). SPP is being further developed and tested at DWD as part of the GLORI Project.

In this subtask we propose to carry out an activity in the COSMO Consortium to support the implementation and testing of SPP in ICON and to adapt the implementation to the different domains and ensemble configurations of the COSMO members.

The work in this subtask consists of:

* support (and contribute to?) the implementation of the SPP scheme for a set of ICON physics parameters. The parameters will be selected together with the developers of the physics and in collaboration with WG PHY. The implementation will be done for each parameter separately, different groups can also work in parallel. The implementation will be progressively included in the master version of ICON.
* for each parameter, test the configuration of the perturbation method by varying the parameters of the SPP scheme itself (variance and horizontal and temporal scale of the SPG, distribution of the parameter, ranges, …). These tests will be performed on different domains and with different ensemble configurations.
* the results of the previously described sensitivity experiments will be discussed with the WG PHY and with the other ICON physics developers.
* for large domains, tuning parameters values may vary at different parts of the domain. It will be therefore test the implementation of a smooth array of tuning parameters over a given domain instead of a constant parameter for the entire domain
* once the optimal configuration is identified for each parameter, test the SPP method in a real ensemble configuration by perturbing all the selected parameters, and compare with the reference ensembles: ensemble with no mode perturbation and ensemble with the operational perturbation method (SPPT, CPP). The experiments will be performed on different domains and with different ensembles, according to the Members which are participating.
* summarise the implementation and configuration in a report and write a scientific paper

For the verification of the experiments, we need to use the same methods and tools. It is important to use the COSMO verification software and to share the other tools developed in the projects (see Task 3). For the verification of the experiments, we will coordinate with WG V/A and have meetings with verification experts.

*Deliverable: SPP implemented in ICON (support), included the possibility to configure* different tuning parameters values at different regions of the domain. *Report and paper.*

*Involved scientists: Zahra Parsakhoo (0.4 FTE/year), Christoph Gebhardt (0.1 FTE/year) (DWD), NN (0.3 FTE/year, Chiara Marsigli (0.1 FTE/year) (Arpae), … (IMS), … (MCH), … (IMGW), … (CNMCA). It is important to have the support of the ICON developers and to work in close contact with the ICON gatekeepers*

FTEs for subtask 1.1: 4 FTE (Dec 2025 – Nov 2027)

**Subtask 1.2 – Other model perturbations**

Xxx

* xxx

*Deliverable: xxx.*

*Involved scientists: xxx*

FTEs for subtask 1.2: x FTE/year (x)

**Subtask 1.3 - ICON-LEPS: model perturbation in ICON-LAM at 2.5 km over the full Mediterranean domain**

Once the transition to ICON-LEPS at 2.5 km is completed, model perturbation will be introduced in the ensemble. A set of parameter of the ICON model will be selected for perturbation and tested in the ICON-LEPS suite. Verification against the non-perturbed ICON-LEPS will be performed and eventually perturbation will be introduced.

If resources will still be available, SPP perturbation will also be tested in the second year (2027).

*Deliverable: Introduction of model perturbations in ICON- LEPS.*

*Involved scientists: NN ((0.3 FTE) E. Minguzzi (0.1 FTE) Arpae) …?*

FTEs for subtask 1.3: 0.5 FTE (March 2026 – Dec 2026)

**Subtask 1.4 - Assess the feasibility to run ICON-LEPS with IC/BC from ICON-EU-EPS**

* Assess the feasibility of ICON-LEPS with IFS-EPS or ICON-EU-EPS BC for operational runs (availability of BC data, computing costs, availability of forecasts, data provision to customers also in view of larger files/total amount compared to COSMO-LEPS)
* Is the ICON-EU-EPS domain large enough to ‘feed’ the new ICON-LEPS domain (critical at the southern boundary)?
* For new (or old BCs): random choice vs. clustering for BC members (see khain et al., <https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/met.2137>

*Deliverable: an answer to the question if it is possible to* run ICON-LEPS with IC/LB from ICON-EU-EPS*.*

*Involved scientists: xxx?*

FTEs for subtask 1.4: x (x)

**Task 2 Ensemble for Nowcasting**

During the last years IMS has implemented operationally two ensemble systems. The first, ICON-IL-EPS-20 runs twice daily with a lead time of 120h and aims to provide the standard probabilistic forecasting products. The second, ICON-IL-EPS-50 runs twice daily only during rainy days with a lead time of 30h. This system aims to provide precipitation nowcasting as described below. Both systems are running at 2.5 km resolution and are driven by EC-ENS. The goals of the tasks below are to utilize these ensemble systems to establish and improve nowcasting of precipitation and surface fields using the so-called best-member approach.

**Subtask 2.1 – Nowcasting of precipitation**

In this subtask, we utilize the ICON-IL-EPS-50 ensemble to improve precipitation nowcasting. This ensemble runs twice daily only during rainy days with a lead time of 30h. Then, every hour, all the 50 members are automatically verified versus the radar data during the last hour, using FSS, and the best member for the given time is defined. Then this member is rerun till that hour with radar-data assimilation (LHN) and then continued for free run for additional 12 hours. This best member serves as deterministic precipitation nowcast at IMS (for lead times of 1-12 hours).

The plan is to improve the best member detection algorithm which, besides surface precipitation verification, will include:

* ICON lightning potential index verification versus ground lightning measurements and MTG lightning Imager.
* ICON cloud cover verification versus cloud mask from EUMETSAT Satellite Application Facility on Climate Monitoring (CM SAF).
* ICON 3-dimensional wind vector verification versus EUMETSAT MTG FCI L2 AMV (Atmospheric Motion Vector) product.
* ICON reflectivity (dbz) verification versus radar reflectivity data.

**Subtask 2.2 – nowcasting of surface fields**

Besides precipitation nowcasting, there is a need to produce nowcasting for surface fields, such as temperature, relative humidity, wind and gust speed, etc. Due to computer resources limitation and lower variability of surface fields, we will not run a 50-members ensemble for this purpose. However, the 20-members ensemble (ICON-IL-EPS-20) routinely running at IMS, can be directly utilized for this purpose. Every hour, ICON-IL-EPS-20 members will be automatically verified versus the synoptic observations during the last hour, and the best member for the given time is defined. Then this member is simply used for nowcasting, without a need to rerun it. Besides regular nowcasting, this approach allows to provide alerts for high-impact events, such as fog, strong winds and wind gusts, extreme heat-stress, etc., several hours in advance.

*Deliverable: Implementation and verification of the Best member approach for different lead times.*

*Involved scientists: Pavel Khain (IMS), Yoav Levi (IMS): 0.5 FTEs per year*

*FTEs for subtask 2.3: 1 FTE (December 2025 – Nov 2028)*

**Task 3 Ensemble verification and diagnostics**

The purpose of this Task is to support the ensemble development and usage by having a common set of methods and tools used for ensemble verification and diagnostics. This Task is needed also to support the SPP implementation and test (Task 1.1), and to evaluate the ICON-LEPS skill relative to other ensembles. In additions, the newly developed AI-based ensembles will need to be verified and properly compared with the currently operational NWP ensembles and this Task provides the methods to ensure and establish a proper verification methodology for this purpose.

**Subtask 3.1 – Use the common software for ensemble verification**

The work of this subtask aims at supporting and expanding the verification of the different ensembles, including ICON-LEPS, with the COSMO software, in order to have more comparable verification results. We would like to use the tool not only for the operational verification but also for the verification of the experiments, in order to have results which are more meaningfully compared.

The work is based on the achievements of the CARMENs PP and supports and complement the operational ensemble verification performed in WG V/A. The COSMO Members running ensembles have the COSMO software installed at their Services and are able to use it to perform the verification of the ensembles.

* Where this is not possible yet, the first activity is to support the CARMENs PP for the verification of the ensemble (FTEs accounted for only in CARMENs).
* Select a test period on which all the ensembles are verified and the results are compared and discussed (or is it already done as part of the common plot activity?)
* Calculate the ICON-LEPS skill relative to IFS-EPS, ICON-EU-EPS, COSMO-IT EPS/ ICON-IT EPS, ICON-IL-EPS, ICON-CH2-EPS, ICON-CH1-EPS, COSMO-TLE(PO), and the control LEPS skill relative to the deterministic models including ICON-GR2.5 and ICON-RO2.8.

*Deliverable: A short report including the skill of the various ensembles including ICON-LEPS on a test period.*

*Involved scientists: xxx (x) all!*

FTEs for subtask 3.3: 1 FTE (Dec 2025 – Feb 2026)

**Subtask 3.2 – Spatial verification methods for ensembles**

The work in this subtask deals with developing and/or testing methods to perform the spatial verification of the ensembles for precipitation, clouds, objects (e.g. thunderstorms). The purpose is to compare the verification results for the evaluation of the experiments, especially for the development of the SPP. Here the focus is on the variables which are not possible to verify with the method implemented in FFV2. This work will be coordinated with WG V/A.

The work will be organised as follows:

* Review the spatial / objects verification methods used in the Consortium and applicable to the ensembles; review the existing tools
* Agree on a method / tool or set of tools to be used for ensemble verification; share the tools

*Deliverable: Agreement about spatial verification methods and tools.*

*Involved scientists: xxx (xxx) all!*

FTEs for subtask 3.2: 1 (x)

**Subtask 3.3 – Diagnostics for ensembles**

This subtask deals with the development and test of diagnostics to assess the ensemble behaviour, in particular the spread/skill relation. We need to compute the spread/skill relation also for variables for which the RMS-based spread/skill relation computed in FFV2 is not appropriate, and we need to also include observational error and consider the presence of model biases in the computation. This work will be coordinated with WG V/A. The activity is organised as follows:

* review the methods already available thanks to the two previous subtasks for diagnosing the ensemble behaviour and identify what is missing
* review the literature about spread/skill quantification for non-gaussian variables or in presence of observational error and model biases
* select the methods which we want to use in the Consortium for ensemble diagnostics, implement them or test them and share the tools. In particular, study how to include observational error and account for model biases in the spread/skill relation
* the Members will use the same methods for ensemble diagnostics, in particular for the SPP development

*Deliverable: Agreement about how to assess the spread/skill relation, develop and share the tools.*

*Involved scientists: xxx (DWD), xxx (MCH), xxx (IMS), NN (0.2/year) (Arpae)*

FTEs for subtask 3.3: 2 (March 2026 – December 2028)

**Task 4 - Merging two ensembles to create one product**

As there are overlapping areas between ICON-LEPS and the national EPSs, a method to create probabilities based on two or perhaps more ensembles for the end user is required. The goal would be to merge the ensembles and not to create use the simple poor man ensemble method.

*Deliverable:*

**Participants**

FTEs for task 4 (x)

**Task 5 - Presentation and dissemination**

If we find out that LEPS skill is good, we will need the think how to enhance the [current](https://www.cosmo-model.org/content/tasks/leps/boxgrams/default.htm) presentation of the LEPS results.

*Deliverable:*a document with the layout for presenting ICON-LEPS in COSMO website and disseminating raw data to clients.

**Participants**

Theodore Andreadis (HNMS)

FTEs for task 5 (x)

**Risks**

human resources

results of the research

**Participants**

Arpae: xxx

Itaf-Met: xxx

DWD: xxx

HNMS: ?

IMGW: xxx

IMS: xxx

**References**

PREVUE

\*\*P\*\*erturbation, \*\*R\*\*epresentation, \*\*E\*\*valuation, \*\*V\*\*erification, and \*\*U\*\*tilization of \*\*E\*\*PS

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### Full Interpretation:

\* \*\*Perturbation\*\* – addresses model perturbation strategies within EPS.

\* \*\*Representation\*\* – covers how uncertainties and ensemble structures are formulated and understood.

\* \*\*Evaluation Verification\*\* – reflect the core focus on assessing the skill and reliability of ensemble forecasts.

\* \*\*Utilization\*\* – emphasizes the diagnostic and exploratory use of EPS, particularly for short-range applications like nowcasting.

\* \*\*EPS\*\* – Ensemble Prediction Systems remain central.

**Appendix 2: Model perturbations.**

The most widely used model perturbation methodologies are here listed and shortly described:

PP (Perturbed Parameters): each member has a different value of one or several parameters, fixed during the integration (also referred to as CPP, Constant Perturbed Parameters)

RPP (Random Perturbed Parameters): each member has a different value of one or several parameters, fixed during the integration, but the value of the parameter is randomly chosen for each cycle and member

RP (Random Parameters): each member has a different value of one or several parameters, fixed in space during the integration but varying in time; the value of the parameter is randomly chosen for each cycle and member

SPPT (Stochastically Perturbed Parametrization Tendency): stochastically perturbed physical tendency, with spatial and temporal correlation

iSPPT (independent SPPT): as SPPT but the tendency from each parametrization scheme is perturbed using an independent stochastic pattern.

SPP (Stochastically Perturbed Parametrisations): physics parameters are stochastically perturbed with spatial and temporal correlation

PSP (Physically Based Stochastic Perturbations): Boundary Layer stochastic perturbations with amplitude based on information obtained from turbulence parameterization, with spatial and temporal correlation

Multi-physics: different members use different physics schemes, fixed

Multi-model: different members use different models, fixed

Stochastic parametrisation: a scheme for parametrising a physical process in the model which is intrinsically stochastic

**Appendix 3: ICON-LEPS**

COSMO-LEPS is the Limited Area Ensemble Prediction System developed within the COSMO consortium to improve the short-to-medium-range forecast of extreme and localised weather events. The current 20 members with 7 km resolution have low benefits compared to the 50 members of IFS EPS with 9 km resolution and the 40 members of DWD ICON-EU with 13 km resolution. Therefore, if the LEPS project would continue upgrading the model to run at a convective-permitting resolution is needed. As such an upgrade requires substantial computation resources, verification and skill assessment relative to other EPSs is needed for the decision to continue with the LEPS initiative.

**Users**

European Flood Awareness System (EFAS)

COSMO Members

COSMO webpage